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Hydrogen generators using fuel processing technologies

Générateurs d'hydrogène utilisant les technologies de traitement du carburant

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Contents

Page

Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 16110 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies.*

Introduction

The machine concerned and the extent to which hazards, hazardous situations and events are covered are indicated in the scope of this document.

This document provides requirements and recommendations relating to hydrogen generators using fuel-processing technologies so as to promote:

- safety of persons and property;
- consistency of control response;
- ease of maintenance.

High performance is not to be obtained at the expense of the essential factors mentioned above.

Hydrogen generators using fuel processing technologies

1 Scope

1.1 This document is a product safety standard suitable for conformity assessment as stated in IEC Guide 104:1997, ISO/IEC Guide 51:1999 and ISO/IEC Guide 7:1994.

1.2 This standard applies to packaged, self-contained or factory matched hydrogen generation systems with a capacity less than 400 Nm^3/hr, herein referred as hydrogen generators, that convert a fuel to a hydrogen rich stream of composition and conditions suitable for the type of device (e.g. fuel cells) using the hydrogen.

1.3 For the purpose of this standard, a hydrogen generator is a configuration of the following assemblies:

— Fuel Processing System

The fuel processing system is a sequence of catalytic or chemical reactors that convert the fuel to a hydrogen rich stream of pre-specified composition and conditions. A fuel processing system may include the following steps:

- fuel cleanup, in which the fuel may be filtered or desulfurized
- primary conversion, in which the fuel is reacted mostly to hydrogen, carbon dioxide, and carbon monoxide by means such as steam reforming, auto-thermal reforming, or catalytic partial oxidation
- water-gas shift conversion, in which carbon monoxide reacts with steam to produce additional hydrogen
- purification, in which carbon monoxide and other impurities are removed from the hydrogen rich product stream
- conditioning, in which the stream temperature and humidity are adjusted to levels suitable for the type of device using the hydrogen
- tail gas combustion, in which unreacted fuel and unused hydrogen are burned in a catalytic or non-catalytic manner prior their release to the environment.

— Fluid Management System

The fluid management system may meter, condition, and process fluids, or adjust the fluid pressure for use within the hydrogen generator. These fluids may be reactants such as air (oxidant), fuel, water (or steam), intermediate product streams, or utility fluids such as inert gas and heat transfer fluids (water, oil). The fluid management system may include complex sub-systems such as steam generators, compressors and water treatment units.

— Thermal Management System

The thermal management system uses heat and mass exchange networks to minimize external heating, and cooling requirements as well as water consumption and energy losses by linking hot and cold process streams in a thermodynamically advantageous way.

— Automatic Control System

The automatic process control system may comprise mechanical, hydraulic, pneumatic, electrical, electronic and/or programmable electronic, and computer hardware/software elements (e.g. sensors, actuators, valves, switches and logic components) that regulate the efficient interaction of all components in order to maintain the process parameters within pre-specified limits without manual intervention.

— Electrical System

The electrical system may comprise of circuits and devices that regulate and distributes electrical power within the hydrogen generator.

— Frame

The frame is an assembly of structural members (for the most part metallic) hold together through permanent or screw-type joints. It carries the hydrogen generator body and its equipment and components, providing accuracy of location as well as strength and rigidity of support.

— Cabinet

The cabinet is a rigid structure that may contain the hydrogen generator and protect it against specific environmental and climatic conditions and incidental contact by people and livestock. It may also provide protection to people and livestock against incidental contact with hazardous parts or materials. Cabinets may include ventilation to allow for the circulation of external air through the interior compartments to remove excess heat and hazardous fumes or vapours.

— Interconnection Piping

The hydrogen generator may include part or all of the interconnection piping, joints and fittings, if these components carry fluids with special material or design requirements. In particular, the hydrogen generator may include a venting system and the interconnection piping used to deliver the gaseous hydrogen containing product stream to distributed components that may or may not be factory matched, e.g. a fuel cell power system or a hydrogen compression, storage and delivery system.

1.4 Hydrogen generators examined for compliance with this standard shall be for use with the following input fuels:

a) Natural gas and other methane rich gases derived from renewable (biomass) or fossil fuel sources, e.g. landfill gas, digester gas, coal mine gas.

b) Fuels derived from oil refining, e.g. diesel, gasoline, kerosene, liquefied petroleum gases such as propane and butane.

c) Alcohols, esters, ethers, aldehydes, ketones, Fischer-Tropsch liquids and other suitable hydrogen-rich organic compounds derived from renewable (biomass) or fossil fuel sources, e.g. methanol, ethanol, di-methyl ether, biodiesel.

d) Gaseous mixtures containing hydrogen gas, e.g. synthesis gas, town gas.

1.5 This standard is applicable to stationary hydrogen generators intended for indoor and outdoor commercial, industrial and residential use.

1.6 **T**his standard contemplates all significant hazards, hazardous situations and events relevant to hydrogen generators, when they are used as intended and under the conditions foreseen by the manufacturer.

1.7 The requirements of this standard are not intended to constrain innovation. The manufacturer may consider fuels, materials, designs or constructions not specifically dealt with in this document. These alternatives shall be evaluated as to their ability to yield levels of safety and performance equivalent to those prescribed by this standard**.**

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASME B31.3-2002 ASME Code for Pressure Piping, B31 Section 3 Process Piping, an American National Standard

IEC 60034 Rotating electrical machines

IEC 60034-1 Rotating electrical machines – Part 1: Rating and performance

IEC 60034-5 Rotating electrical machines – Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines

IEC 60068-2-18 Environmental Testing —Part 2 – 18: Tests — Test R and Guidance: Water

IEC 60079-10 Electrical Apparatus for Explosive Gas Atmospheres — Part 10: Classification of hazardous areas

IEC 60146 Semiconductor convertors

IEC 60146-1-1 Semiconductor convertors - General requirements and line commutated convertors Part 1-1: Specifications of basic requirements

IEC 60204-1 Electrical Equipment of Industrial Machines — Part 1: General requirements

IEC 60335-1 Household and similar electrical appliances - Safety - Part 1: General requirements

IEC 60335-2-41 Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps

IEC 60335-2-51 Household and similar electrical appliances - Safety - Part 2-51: Particular requirements for stationary circulation pumps for heating and service water installations

IEC 60364-4-41 Electrical protection of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock

IEC 60417 Graphical symbols for use on equipment. Index, survey and compilation of the single sheets

IEC 60439-1 Low voltage switchgear and control gear assemblies – Part 1: Type-tested and partially type-tested assemblies

IEC 60529 Degrees of protection provided by enclosures (IP Code)

IEC 60534-1 Industrial-process control valves. Part 1: Control valve terminology and general considerations

IEC 60704-3 Test Code for the Determination of Airborne Acoustical Noise Emitted by Household and Similar Electrical Appliances Part 3: Procedure for Determining and Verifying Declared Noise Emission Values First Edition; CENELEC EN 60704-3

IEC 60730-1. Automatic electrical controls for household and similar use – General requirements

IEC 60730-2-5 Automatic electrical controls for household and similar use - Part 2-5: Particular requirements for automatic electrical burner control systems

IEC 60730-2-6 Automatic electrical controls for household and similar use - Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements

IEC 60730-2-9 Automatic electrical controls for household and similar use - Part 2-9: Particular requirements for temperature sensing controls

IEC 60730-2-17 Automatic electrical controls for household and similar use - Part 2-17: Particular requirements for electrically operated gas valves, including mechanical requirements

IEC 60730-2-19 Automatic electrical controls for household and similar use - Part 2-19: Particular requirements for electrically operated oil valves, including mechanical requirements

IEC 60812 Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)

IEC 60990:1999 Methods of Measurement of Touch Current and Protective Conductor Current

IEC 61000-6-1, Electromagnetic compatibility - Part 6-1: Generic standards - Immunity for residential, commercial and light industrial environments

IEC 61000-6-2, Electromagnetic compatibility – Part 6-2: Generic standard – Immunity for industrial environments

IEC 61000-6-3, Electromagnetic compatibility - Part 6-3: Generic standards - Emission standard for residential, commercial and light industrial environments

IEC 61000-6-4, Electromagnetic compatibility – Part 6-4: Generic standard – Emission standard for industrial environments

IEC 61000-3-2, Electromagnetic compatibility (EMC) Part 3-2: Limits for harmonic currents emissions (equipment input current up to 16 A per phase)

IEC 61000-3-3, Electromagnetic compatibility (EMC) Part 3-3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current up to 16 A.

IEC 61000-3-4, Electromagnetic compatibility (EMC) Part 3-4: Limits – Limitation of emission of harmonic currents emissions in low-voltage power supply systems for equipment with rated current greater than 16 A

IEC 61000-3-5, Electromagnetic compatibility (EMC) Part 3-5: Limits - Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current greater then 16 A

IEC 61025 Fault tree analysis (FTA)

IEC 61061 Safety of machinery- Functional safety of electrical, electronic and programmable control systems

IEC 61131-1 Programmable controllers – Part 1: General information

IEC 61131-2 Programmable controllers – Part 2: Equipment required and tests

IEC 61140 Protection against electric shock – Common aspects for installation and equipment

IEC 61340-2-1 Electrostatics - Part 2-1: Measurement methods - Ability of materials and products to dissipate static electric charge

IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems

IEC 61511 Functional Safety: Safety Instrumented for the Process Industry Sector - Part 3: Guidelines in the Application of Hazard and Risk Analysis

IEC 61779-4 Electrical apparatus for the detection and measurement of flammable gases – Part 4: Performance requirements for Group II Apparatus indicating a volume fraction up to 100-percent lower explosive limit

IEC 61779-6 Electrical apparatus for the detection and measurement of flammable gases – Part 6: Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of flammable gases

IEC 61882, Hazard and operability studies (HAZOP studies) - Application guide

IEC 62086-1, Electrical apparatus for explosive gas atmospheres – Electrical resistance trace heating – Part 1: General and testing requirements

IEC Guide 104:1997 The preparation of safety publications and the use of basic safety publications and group safety publications

ISO 3864 Safety Colors and safety signs

ISO 4080 Rubber and Plastics Hoses and Hose Assemblies – Determination of Permeability to Gas

ISO 4126-1 Safety valves - Part 1: General requirements

ISO 4126-2 Safety devices for protection against excessive pressure - Part 2: Bursting disc safety devices

ISO 4413 Hydraulic fluid power -general rules relating to systems

ISO 4414 Pneumatic fluid power -general rules relating to systems

ISO 4898: Labelling and marking of products

ISO 5199 Technical Specifications for Centrifugal Pumps - Class II

ISO 9300 Measurement of gas flow by means of critical flow Venturi nozzles

ISO 9905 Technical Specifications for Centrifugal Pumps - Class I

ISO 9908 Technical Specifications for Centrifugal Pumps - Class III

ISO 7000 Graphical symbols for use on equipment – Index and synopsis

ISO 10431 Petroleum and Natural Gas Industries - Pumping Units – Specification

ISO 10440-1 Petroleum and natural gas industries — Rotary-type positive- displacement compressors — Part 1: Process compressors (oil-free)

ISO 10440-2 Petroleum and natural gas industries -- Rotary-type positive- displacement compressors – Part 2: Packaged air compressors (oil-free)

ISO 13707 Petroleum and natural gas industries – Reciprocating Compressors

ISO 13709 Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries

ISO 13850 Safety of machinery — Emergency stop — Principles for design

ISO 14121 Safety of machinery – Principles of risk assessment

ISO 14847 Rotary Positive Displacement Pumps - Technical Requirements

ISO 12499:1999 Industrial fans -- Mechanical safety of fans -- Guarding

ISO 15649: 2001 Petroleum and Natural Gas Industries – Piping (See also ASME B31.3)

ISO/TR 15916 Basic considerations for the safety of hydrogen systems

ISO TS 16528 Boilers and pressure vessels -- Registration of codes and standards to promote international recognition

ISO/IEC Guide 51:1999, Safety aspects – Guidelines for their inclusion in standards

ISO/IEC Guide 7:1994, Guidelines for drafting of standards suitable for use for conformity assessment

3 Terms and Definitions

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
acceptance test
Contractual test to prove to the customer that an item meets certain conditions of its specifications.
[IEV 151-16-23]

3.2
air-rich systems
Systems containing mixtures of fuel and air, in which the air content is greater than under stoichiometric mixture. Air-rich conditions are used when complete fuel reaction is intended (e.g. in flame burners).

3.3
alcohol
Any of a series of hydroxyl compounds, the simplest of which are derived from saturated hydrocarbons, have the general formula $C_nH_{2n+1}OH$.

3.4
aldehydes
Any of a class of highly reactive organic chemical compounds obtained by oxidation of primary alcohols, characterized by the common group CHO, and used in the manufacture of resins, dyes, and organic acids.

3.5
ambient temperature
Temperature of the medium surrounding a device, equipment or installation that may affect the performance of the device, equipment or installation.

3.6
Area classification
Areas are classified based upon the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- Zone 0: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently [IEV 426-03-03, modified];
- Zone 1: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally [IEV 426-03-04, modified];
- Zone 2 place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only [IEV 426-03-05, modified];

  NOTE 1 In this definition, the word "persist" means the total time for which the flammable atmosphere will exist. This will normally comprise the total of the duration of the release, plus the time taken for the flammable atmosphere to disperse after the release has stopped. (The term "persistence time" as used in annex B refers specifically to only one part of the total time for which the flammable atmosphere will exist.).

NOTE 2 Indications of the frequency of the occurrence and duration may be taken from codes relating to specific industries or applications.

3.7
Auto-ignition temperature
The auto-ignition temperature of a substance is the lowest temperature at which the said substance will ignite without an external source of ignition. [IEC 60079-20]

3.8
Automatic control system
Assembly of sensors, actuators, valves, switches and logic components (including process controllers) that maintains the *hydrogen generator* parameters within the manufacturers specified limits without manual intervention.

3.9
Automatic recycling
The automatic repetition of the start-up procedure without manual intervention, following loss of the supervised flame and subsequent fuel supply shut off. [IEC 60730-2-5]

3.10
Auto-thermal reforming
The coupling of partial oxidation and steam reforming.

3.11
Burner control system
System which monitors the operation of fuel burners. It includes a programming unit, a flame detector and may include an ignition source and / or ignition device.
[IEC 60730-2-5]

3.12
Catalytic partial oxidation reforming
Exothermic conversion of a hydrocarbon with a small quantity of air for the generation of hydrogen over a catalyst.

3.13
Coal-mine gas
As coal mining proceeds, methane contained in the coal and surrounding strata may be released. This methane is referred to as coal mine methane or coal mine gas since its liberation resulted from mining activity. In some instances, methane that continues to be released from the coal bearing strata once a mine is closed and sealed may also be referred to as coal mine methane because the liberated methane is associated with a coal mine.

3.14
Combustible gas, liquid or vapour
Gas, liquid or vapour which, when mixed with air or oxygen, is capable of the propagation of flame away from the source of ignition when ignited.

3.15
Commercial
Application in which the hydrogen generator is used by laymen in non-manufacturing business establishments such as stores, hotels, office buildings, educational institutes, refilling stations.

3.16
Concealed location
A location that cannot be accessed without damaging permanent parts of a building structure or finish surface. Spaces above, below or behind readily removable panels or doors shall not be considered as concealed.

3.17
Concealed piping
Piping that is located in a concealed location.

3.18
Conformity assessment
Process of evaluation and approval of products, services, systems, processes and materials against standards, regulations or other agreed specifications. As applicable, the conformity assessment can be performed by the supplier organization itself (First-party assessment, self-assessment), by a customer of the supplier organization (Second-party assessment) or by a body that is independent of both supplier and customer organizations (Third-party assessment, Certification/ registration). Such third-party assessment may be required in certain business sectors by government regulations, it may be specified by the customer, or the supplier organization may choose it as a way of differentiating its product or service from others on the market.

3.19
Controlled shutdown
For air-rich operation, de-energization of the main fuel flow means, or for fuel-rich operation, the de-energization of both the process air flow and main flow means, as the result of the opening of a control loop by a control device such as a thermostat. The system returns to the start position.
[IEC 60730-2-5]

3.20
Controlled stops
Stopping with power available to the generator actuators to achieve the stop and then removal of power when the stop is achieved.

3.21
Critical failure mode
A failure mode of a software or hardware item is critical if it can result in unacceptable risk of harm.

3.222
Design Pressure
Pressure value applied to the design of pressure containing components in a hydrogen generation system. The design pressure of each component shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service except as provided in ISO 15649 for piping and in the applicable regional or national pressure equipment codes and standards for other pressure equipment.

3.23
Design Temperature
Temperature value applied to the design of pressure containing components in a hydrogen generation system. The design temperature of each component shall be not less (or more) than the temperature at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service except as provided in ISO 15649 for piping and in the applicable regional or national pressure equipment codes and standards for other pressure equipment.

3.24
Digester gas
The gas produced as a result of the microbial decomposition of particulate organic matter under anaerobic conditions. Methane and hydrogen are major components.

3.25
Direct ignition
A type of ignition which is applied directly to the main burner, without the use of a pilot.
[IEC 60730-2-5]

3.26
Discharge water
Water discarded from the hydrogen generator including waste water and condensate.
[IEC 62282-1 TS Ed. 1 105/64/DTS 9]

3.27
Electromagnetic compatibility (EMC)
Ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.
[IEV 161-01-07]

3.28
Ester
Any of a class of organic compounds corresponding to the inorganic salts and formed from an organic acid and an alcohol.

3.29
Ether
Any of a class of organic compounds in which two hydrocarbon groups are linked by an oxygen atom.

3.30
Explosive atmosphere
Mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, mist or dust, in which after ignition, combustion spreads throughout the unconsumed mixture.
[IEV 426-02-02, modified]

3.31
Explosive gas atmosphere
Mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour in which, after ignition, combustion spreads throughout the unconsumed mixture.
[IEV 426-02-03, modified]

NOTE Although a mixture which has a concentration above the upper explosive limit (UEL) is not an explosive gas atmosphere, it can readily become so and, in certain cases for area classification purposes, it is advisable to consider it as an explosive gas atmosphere.

3.32
Explosive limits
The terms "explosive limit" and "flammable limit" are widely used as equivalent. IEC 60079-20 and IEC 61779-1 use the term "flammable limit" whilst most other standards use the more widely accepted term "explosive limit". ISO TR 15916 uses detonable limits. The only substance for which the explosive limit is significantly different from the flammable limit is Hydrogen.

3.33
Extent of zone
Distance in any direction from the source of release to the point where the gas/air mixture has been diluted by air to a value below the lower explosive limit.
[IEC 60079-10]

3.34
Factory matched unit
System components engineered in a factory to correspond with each other and work together, separately packed for storage and transportation to be assembled together at the point of utilization.

3.35
Fischer-Tropsch liquids
Liquids derived through a technology based on the Fischer-Tropsch process, e.g. gas-to-liquids (GTL), methanol-to-gasoline (MTG), methanol-to-olefins (MTO), methanol-to-propylene (MTP), methanol-to-olefins-to-gasoline and distillates (MOGD), dimethyl ether (DME) processes, etc.

3.36
Fischer-Tropsch process
Method for the synthesis of hydrocarbons and other aliphatic compounds. Synthesis gas, a mixture of hydrogen and carbon monoxide, is reacted in the presence of an iron or cobalt catalyst; much heat is evolved, and such products as methane, synthetic gasoline and waxes, and alcohols are made, with water or carbon dioxide produced as a byproduct. The process is named after F. Fischer and H. Tropsch, the German coal researchers who discovered it in 1923.

3.37
Flame detector
Device that provides the programming unit with a signal indicating the presence or absence of flame. It includes the flame sensor and may include an amplifier and a relay for signal transmission. The amplifier and relay may be in its own housing or combined with the programming unit. [IEC 60730-2-5]

3.38
Flame detector response time
The period of time between the loss of the sensed flame and the signal indicating the absence of flame.
[IEC 60730-2-5]

3.39
Flame sensor
Device that detects the flame and provides input signal to the flame detector amplifier, e.g. optical sensors and flame electrodes (flame rods).
[IEC 60730-2-5]

3.40
Flame failure lock-out time
The period of time between the signal indicating absence of flame and lock-out.
[IEC 60730-2-5]

3.41
Flame failure recognition time
The period of time between the signal indicating absence of flame and the signal to energize the ignition device. During this time period, the fuel supply is not shut off.
[IEC 60730-2-5]

3.42
Flame failure re-ignition time (relight time)
Period of time between the signal indicating absence of flame and the signal to energize the ignition device. During this period the fuel supply is not shutoff.
[IEC 60730-2-5]

3.43
Flammable gas or vapour
Gas or vapour which, when mixed with air in certain proportions, is capable of the propagation of flame away from the source of ignition when ignited.

3.44
Flammable liquid
Liquid capable of producing a flammable vapour under any foreseeable operating conditions.

3.45
Flammable material (flammable substance)
Material that is flammable of itself, or is capable of producing a flammable gas, vapour or mist.

3.46
Flashback
A recession of a flame into or back of the mixing chamber.

3.47
Frequency
Probability of occurrence of an incident.

3.48
Fuel
Chemical substance fed to the hydrogen generator as a reactant or as input energy. Usually composed by natural gas, other hydrocarbons, alcohols or other organic compounds.

3.49
Fuel-air ratio
This is the ratio of the mass of fuel to the mass of air in the reactants. The fuel-air ratio is a method of measuring the composition of a potentially flammable mixture.

3.50
Fuel cell
Electrochemical device that converts the chemical energy of a fuel (such as hydrogen or hydrogen rich gases, alcohols, hydrocarbons) and an oxidant to DC power, heat and other reaction products A fuel cell is an electrochemical device in which hydrogen and oxygen combine in a controlled manner (in contrast to combustion or explosion) to directly produce an electric current and heat. Reverse process of electrolyser.

3.51
Fuel cell power system
Generator system that uses a *fuel cell* to convert the chemical energy of reactants (a fuel and an oxidant) to electric energy (direct current or alternate current electricity) and thermal energy.

3.52
Fuel-rich system
System containing mixtures of fuel and air, in which the fuel content is larger than under stoichiometry. Fuel-rich conditions are used when complete air reaction is intended (e.g. in catalytic partial oxidation, preferential oxidation or auto-thermal reactors).

3.53
Gas crossover (fuel)
Leakage between the fuel side and the oxidant side in either direction.
[FC-1]

3.54
Gas leakage/gas release
The sum of all gases leaving the hydrogen generator except the intended exhaust gases.
[modified from IEC 62282-1 TS Ed. 1 105/64/DTS 11]

3.55
Harm
Physical injury or damage to health, property or the environment [ISO/IEC Guide 51:1999], i.e. death, injury, illness, and or damage (loss) of assets, the environment or third parties.

3.56
Hazard
Potential source of harm.
[ISO/IEC Guide 51:1999]

3.57
Hazardous area
Area in which an explosive gas atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of apparatus.
[IEV 426-03-01, modified]
Any area in which a hazard is present

3.58
Hazardous event
Incident that occurs when a hazard is realized.

3.59
Hazardous locations (classified)
Any area or space where combustible dust, ignitable fibres, or flammable, volatile liquids, gases, vapours or mixtures are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

3.60
Hazardous situations
Circumstances in which people, property or the environment are exposed to one or more hazards.
[ISO/IEC Guide 51:1999]

3.61
Hazards
Physical situation with a potential for human injury, damage to property, damage the environment, or some combination of these.

3.62
Hydrocarbon
A compound that contains only hydrogen and carbon, as methane, benzene, etc. Also, by extension, any of its derivatives.

3.63
Hydrogen embrittlement
The process whereby steel components become less resistant to breakage and generally much weaker in tensile strength as a result of exposure to hydrogen.

3.64
Ignition activation period
Period of time between energizing the main gas valve and deactivation of the ignition means prior to the lockout time.

3.65
Ignition device
Device mounted on or adjacent to a burner for igniting fuel at the burner [IEC 60730-2-5].

3.66
Ignition temperature of an explosive gas atmosphere
Lowest temperature of a heated surface at which, under specified conditions, the ignition of a flammable substance in the form of a gas or vapour mixture with air will occur.
[IEV 426-02-01, modified]

NOTE IEC 60079-4 and IEC 60079-4A standardize a method for the determination of this temperature.

3.67
Incident (effect)
Event or chain of events that can, but does not necessarily result in harm.

3.68
Industrial
An application in which the hydrogen generator is used by qualified and experienced personnel in a controlled manufacturing environment a chemical plant or a mine.

3.69
Input fuel
See Fuel.

3.70
Installer
Person qualified to install the hydrogen generator and its associated equipment.

3.71
Intermittent ignition
A type of ignition that is energized when an appliance is called on to operate and which remains continuously energized during each period of main burner operation. The ignition is de-energized when the main burner operating cycle is completed.
[IEC 60730-2-5]

3.72
Intermittent pilot
A pilot which is automatically ignited when an appliance is called on to operate and which remains continuously ignited during each period of main burner operation. The pilot is automatically extinguished when each main burner operating cycle is complete.
[IEC 60730-2-5]

3.73
Interrupted ignition
A type of ignition which is energized prior to the admission of fuel to the main burner and which is de-energized when the main flame is established.
[IEC 60730-2-5]

3.74
Interrupted pilot
A pilot which is automatically ignited prior to the admission of fuel to the main burner and which is automatically extinguished when the main flame is established.
[IEC 60730-2-5]

3.75
Landfill gas
The gas produced as a result of the microbial decomposition of particulate organic waste material under anaerobic conditions. Methane and hydrogen are major components.

3.76
LEL
See Lower explosive limit.

3.77
LFL
See Lower flammability limit.

3.78
Light industrial
An application in which the hydrogen generator is used by personnel with limited qualification and experience in manufacturing environments with limited dedicated controls, e.g. computer and electronics manufacturing facilities.

3.79
Limit gases
Test gases representative of the extreme variations in the characteristics of the gases for which appliances have been designed.
[3.4 of EN437:1993]

3.80
Lock-out
A process in which the burner control system goes into one of tow lockout conditions following safety shutdown.

3.81
Lower explosive limit (LEL)
Concentration of flammable gas or vapour in air, below which the gas atmosphere is not explosive.
[IEV 426-02-09, modified]

3.82
Lower flammability limit (LFL)
Minimum concentration of a flammable gas/vapour in air in which flame is propagated.

3.83
Main flame establishing period
The period of time between the signal to energize the main fuel flow means and the signal indicating presence of the main burner flame.

3.84
Manufacturer
Manufacturer of the hydrogen generator.

3.85
Maximum flame signal (S_{max})
The maximum signal that does not affect the timing s or the sequence.

3.86
Negative pressure ventilation
Movement of air and its replacement with fresh air by artificial suction means, for example fans, and applied to a general area.

3.87
Noise level (power system)
Sound pressure level, expressed as decibels (dBA), generated by the hydrogen generator at the steady state operating condition where it generates maximum noise, and measured at a specified point.

3.88
Non-hazardous area
Area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of apparatus.
[IEV 426-03-02, modified]

3.89
Non-volatile lock-out
The condition of a burner control system following safety shutdown such that a restart can only be accomplished by a manual reset of the burner control system and by no other cause.

3.90
Normal operation
Situation when the equipment is operating within its design parameters.

NOTE 1 Minor releases of flammable material may be part of normal operation. For example, releases from seals which rely on wetting by the fluid that is being pumped are considered to be minor releases.
NOTE 2 Failures (such as the breakdown of pump seals, flange gaskets or spillages caused by accidents) which involve urgent repair or shut-down are not considered to be part of normal operation nor are they considered to be catastrophic.
NOTE 3 Normal operation includes start-up and shut-down conditions.

3.91
Operating mode
A pre-set condition of functioning of the hydrogen generator.

3.92
Packaged unit
A skid or cabinet containing system components pre-assembled in a factory. and engineered to work together in one skid or cabinet.

3.93
Pilot
Flame, smaller than the main flame, which is utilized to ignite the main burner or burners [IEC 60730-2-5].

3.94
Pilot flame establishing period
The period of time between the signal to energize the pilot fuel flow means and the signal indicating presence of the pilot flame.

3.95
Product safety standard
Standard covering all safety aspects of one or more products within the scope of a single ISO Technical Committee.

3.96
Proved ignition system
A burner control system in which the fuel flow means is energized only after the availability of sufficient energy to ignite the fuel has been verified.

3.97
Purge time
The period during which air in introduced to displace any remaining air/fuel mixtures or products of combustion from the combustion zone and flue ways.

3.98
Reaction failure lock-out time
The time between the moment of reaction failure detection and the automatic shut off of the fuel supply for air rich operation, or for fuel-rich operation, of the supply of all reactants.

3.99
Reaction initiation time
The time between the recognition of failure of reaction initiation and the automatic shut off of the fuel supply for air rich operation, or for fuel-rich operation, of the supply of all reactants.

3.100
Recycle time
The period of time between the signal to de-energize the fuel flow means flowing the loss of flame and the signal to begin a new start-up procedure.

3.101
Recycle
Process by which, following an unsuccessful hydrogen generator start up, repeated complete start-up trials are attempted.

3.102
Reference conditions
Arbitrarily chosen conditions for measured volumes of gases when recalculated to a temperature of 20°C and an absolute pressure of 101.3 kPa.
[IEC 62282-1 TS Ed. 1 105/64/DTS 14]

3.103
Reference gases
Test gases on which appliances operate under normal conditions, when they are supplied at the corresponding normal pressure.
[3.3 of EN437:1993]

3.104
Re-ignition
Process by which, following loss of the flame signal, the ignition device will be re-energized without interruption of the fuel flow means.

3.105
Release rate
Quantity of flammable gas or vapour emitted per unit time from the source of release.

3.106
Remote monitoring and control
Keeping track of and influencing process parameters or the performance and condition of a piece of equipment from a remote location.

3.107
Residential
Application in which the hydrogen generator is used by laymen in private households.

3.108
Response time
Time required for a hydrogen generator to transfer from one defined state to another. Note- This may also be quoted as a “response ramp rate” expressed in kW s-1.

3.109
Routine test
Conformity test made on each individual item during or after manufacture.
[IEV 151-16-17]

3.110
Risk
Combination of the frequency, or probability, of occurrence of an event and the consequences of the event.

3.111
Risk analysis
Use of available information to identify hazards and assess risk.

3.112
Risk assessment
Overall process of risk analysis and risk evaluation.

3.13
Risk evaluation
Judgment, on the basis of risk analysis, of whether a risk is tolerated.

3.14
Safeguarding
Procedure for actions of the controlling system based on monitoring of the technical process in order to avoid process conditions which would be hazardous to personnel, plant, product or environment.

3.15
Safety and reliability analysis
A documented and systematic group of activities intended to recognize and evaluate the potential failure of a product/process and the effects of that failure, and to identify actions that could eliminate or reduce the risk of harm of the potential failure occurring.

3.116
Safety shutdown
De-energization of the main fuel flow means as the result of the action of a limiter, a cut-out or the detection of an internal fault of the system. A safety shutdown main include additional actions by the system.

3.117
Self-contained unit
A unit that is complete and independent in itself.

3.118
Severity
Qualitative measure of the worst possible incident (effect) that could be caused by a specific hazard.

3.119
Shutdown time
Duration between the instant when the hydrogen demand is removed at rated throughput and the instant when the shutdown is completed as specified by the manufacturer.

3.120
Signal for absence of flame (S_2)
The maximum signal that indicates the loss of flame.

3.121
Signal for presence of flame (S_1)
The minimum signal that indicates the presence of flame when there was previously no flame.

3.122
Source of release
Point or location from which a flammable gas, vapour, or liquid may be released into the atmosphere in such a way that an explosive gas atmosphere could be formed.
[IEV 426-03-06, modified]

3.123
Standby state
Hydrogen generator being at operating temperature and in an operational mode from which the hydrogen generator is capable of being promptly switched to an operational mode with net hydrogen output.

3.124
Start position
Position which denotes that the system is not in the lock-out condition and has not yet received the start signal, but can proceed with the start-up sequence if required.
[IEC 60730-2-5]

3.125
Start-up energy
The sum of electrical, thermal and/or chemical (fuel) energy required during the start-up time.

3.126
Start-up lock-out time
The period of time between the signal to energize the fuel flow means and lock-out.

3.127
Start-up time
Duration required for transitioning from *cold state* to net hydrogen output.
[IEC 62282-1 TS Ed. 1 105/64/DTS 15 modified].

3.128
Steam reforming
Conversion of a hydrocarbon with water for the generation of hydrogen over a catalyst with input of energy.

3.129
Stoichiometry
The quantitative relationship between reactants and products in a chemical reaction.

3.130
Stoichiometric mixture
Occurs when reactants (e.g. air and fuel) are present in the exact ratio needed for their complete reaction.

3.131
Storage state
Hydrogen generator being non-operational and possibly requiring, under conditions specified by the manufacturer, the input of thermal or electrical energy in order to prevent deterioration of the components.

3.132
System
Composite entity, at any level of complexity, of personnel, procedures, materials, tools, equipment, facilities and software. The elements of this complex entity are used together in the intended operational or support environment to perform a given task or achieve a specific objective.

3.133
Test gases
Gases intended for the verification of the operational characteristics of appliances using combustible gases. They consist of reference gases and limit gases [3.4 of EN437:1993].

3.134
Thermal management system
Provides cooling and heat rejection to maintain thermal equilibrium within the hydrogen generator, and may provide for the recovery of excess heat and assist in heating the unit during startup.

3.135
Thermal stability
Stable temperature conditions, pseudo steady-state, arbitrarily indicated by temperature changes of no more than 3 °C or 1% of the absolute operating temperature, whichever is higher between two readings 15 minutes apart.

3.136
Time to full output
Time taken to change from the standby state to reach 100% of rated power specified by the manufacturer Note- This may also be quoted as “Full Power Ramp Rate” expressed in kW s-1.

3.137
Tolerable/ acceptable risk
Risk that is accepted in a given context based on the current values of society.

3.138
Transition
Process through which the hydrogen generator changes from one operating mode to another.

3.139
Type test
Conformity test made on one or more items representative of the production.
[IEV 151-16-16]

3.140
Uncontrolled stops
Stopping by immediate removal of power.

3.141
Upper explosive limit (UEL)
Concentration of flammable gas or vapour in air, above which the gas atmosphere is not explosive.
[IEV 426-02-10, modified]

3.142
User
One who uses the hydrogen generator with the aid of documentation during the hydrogen generator's normal life. The user is considered a layman.

3.143
Ventilation
Movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (for example, fans or extractors).

3.144
Ventilation system
Part of the hydrogen generator that provides, by mechanical means, air to its cabinet.
3.145
Vibration level
Maximum measurement value of mechanical oscillations produced by the hydrogen generator during operation during all modes Note- This is a value expressed as decibels (dB).

3.146
Volatile lock-out
The condition of a burner control system following safety shutdown such that a restart can be accomplished by either a manual reset of the burner control system or by an interruption of the power supply and its subsequent restoration.

3.147
Waiting time
The period between the start signal and the signal to energize the ignition device. For burners without fans, natural ventilation of the combustion chamber and the flue passages normally takes place during this time.

3.148
Waste heat
Thermal energy released and not recovered.

3.149
Waste water
Excess water that is removed from the hydrogen generator, and which does not constitute part of the thermal recovery system.

3.150
Water treatment system
Provides for treatment and purification of recovered or added water for use within the hydrogen generator.

4 Safety Requirements and Protective Measures

4.1 Safety strategy

4.1.1 Hazard and risk assessment

The manufacturer shall ensure that:

- all foreseeable hazards, hazardous situations and events associated with the hydrogen generators throughout their anticipated lifetime have been identified,

- the risk for each of these hazards has been estimated derived from the combination of probability of occurrence of the hazard and of its foreseeable severity as per ISO 14121, IEC 61882, or IEC 61511-3 as applicable.

- the two factors which determine each one of the estimated risks (probability and severity) have been eliminated or reduced as far as possible through the design (inherently safe design and construction),

- the necessary protection measures in relation to risks that are not eliminated have been taken (provision of warning and safety devices),

- users are informed of any additional safety measures that they may be required to implement.

4.1.2 Safety and Reliability Analysis

The manufacturer shall demonstrate that the necessary protection measures, in relation to risks that are not eliminated, have been taken by performing a safety and reliability analysis which is intended to identify failures that have significant consequences affecting the system performance and/or safety.

The safety and reliability analysis shall be performed as per IEC 60812, IEC 61025, or equivalent.

4.2 Physical environment and operating conditions

The hydrogen generator and protective systems shall be so designed and constructed as to be capable of performing their intended function in the physical environment and operating conditions specified in 4.2.1 to 4.2.7.

4.2.1 Electrical power input

The hydrogen generator power input shall meet the conditions specified in IEC 60204-1 or, in the case of a special source of supply such as a fuel cell, as otherwise specified by the manufacturer.

4.2.2 Physical environment

The manufacturer shall specify the physical environment conditions for which the hydrogen generator is suitable. Consideration shall be given:

- to indoor and/or outdoor use,

- to the altitude above sea level up to which the hydrogen generator shall be capable of operating correctly,

- to the range of air temperatures and humidity within which the hydrogen generator shall be capable of operating as intended,

- to seismic or earthquake compatibility, and

- to the suitability of the hydrogen generator to operate in hazardous locations.

4.2.3 Fuel Input

The hydrogen generator shall be designed to operate as intended within the composition limits and supply characteristics of the fuels for which its design is intended. The manufacturer shall specify in the product's technical documentation the composition limits and supply characteristics of the fuels to be used in the hydrogen generator. See also Section 5.2.

4.2.4 Water Input

The manufacturer shall specify in the product's technical documentation the quality and supply characteristics of the water to be used in the hydrogen generator.

4.2.5 Vibrations, shock and bump

The hydrogen generator shall be designed to withstand, or suitable means shall be provided to protect against, the effects of vibrations, shock and bump (including those generated by the operation of the generator and its associated equipment and those created by the physical environment). This may be accomplished by selecting suitable equipment, mounting the source of vibration away from the hydrogen generator, or using anti-vibration mountings. This does not include the effects of seismic shock, which shall be addressed separately if necessary (see 4.2.2).

4.2.6 Handling, transportation, and storage

The hydrogen generator shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperatures within a range of –25 °C to +55 °C and for short periods not exceeding 24 h at up to +70 °C, as per IEC 60204-1.

The hydrogen generator or each component part thereof shall:

- be capable of being handled and transported safely, when necessary, be provided with suitable means for handling by cranes or similar equipment,

- be packaged or designed so that it can be stored safely and without damage (e.g. adequate stability, special supports, etc.).

The manufacturer shall specify special means for handling, transportation and storage if required.

4.3 General design requirements

The hydrogen generator shall be able to perform, to function, to be transported, installed, adjusted, maintained, dismantled and disposed of under conditions of intended use specified in the hydrogen generator's technical documents without causing an injury or damage to health.

4.3.1 In so far as their purpose allows:

a. Accessible parts of the hydrogen generator shall have no exposed sharp edge and no rough surfaces likely to cause injury.

b. The hydrogen generator or parts of it where persons are intended to move about or stand shall be designed and constructed to prevent persons slipping, tripping or falling on or off these parts.

c. The moving parts of the hydrogen generator shall be designed, built and laid out to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way as to prevent all risk of contact that could lead to accidents.

4.3.2 The manufacturer shall take steps to eliminate any risk of injury caused by contact with or proximity to hydrogen generator parts or materials at high temperatures.

a) Temperatures of surfaces accessible to users

If external surfaces of the hydrogen generator may be contacted by users without personal protective equipment while the hydrogen generator is in operation, the manufacturer shall either limit the temperature of these surfaces as per Table 4.1 or the manufacturer shall fix guards or protective devices in such a way as to prevent risk of contact that could lead to accidents.

Material	**Surface held for short periods**	**Surface held in (continuously) normal use**
	(°C)	(°C)
Metal	35	30
Porcelain	45	40
Plastics	60	50

Table 4.1 Maximum surface temperatures of external components and containment structures that may be contacted during operation by users without personal protective equipment

b) Walls, Floor and Ceiling Temperatures

The temperatures on walls, floor and ceiling adjacent to a hydrogen generator provided with a cabinet shall not exceed 50°C above ambient temperature under the test conditions of section 5.10.a.

c) Temperature of Polymeric Components

Polymeric components equipped onto hydrogen generators (including manufacturer-specified or provided vent systems) shall retain their functional integrity in the intended range of operational temperatures. This provision shall be deemed met if the polymeric components meet the requirements of Section 5.10.

4.3.3 The hydrogen generator, components and fittings thereof shall be so designed and constructed that they are stable enough, under the foreseen operating conditions (if necessary taking climatic and seismic conditions into account) for use without risk of overturning, falling or unexpected movement. Otherwise, appropriate means of anchorage shall be incorporated and indicated in the product's technical documentation.

4.3.4 The various parts of the hydrogen generator and their linkages shall be so constructed that, when used normally, no instability, distortion, breakage or wear likely to impair their safety can occur.

4.3.5 The hydrogen generator shall be so designed, constructed and/or equipped that risks due to gases, liquids, dust, or vapours released during the operation or maintenance of a hydrogen generator, or used in its construction can be avoided.

4.3.6 The hydrogen generator shall be so designed and constructed that the emission of airborne noise is reduced to a level suited for the intended use or location in compliance with applicable regional or national airborne noise codes and standards.

4.3.7 The hydrogen generator exhaust to atmosphere, under normal steady state operating conditions, shall not contain concentrations of carbon monoxide in excess of 300 ppm in an air-free sample of the effluents.

4.3.8 Where explosive, flammable, or toxic fluids are contained in the piping, appropriate precautions shall be taken in the design and marking of sampling and take-off points.

4.3.9 All parts shall be securely mounted or attached and rigidly supported. The use of shock-mounts is permitted when suitable for the application.

4.3.10 All equipment and components whose failure may result in a hazardous event, as identified by the safety and reliability analysis noted in 4.1.2, shall be separately tested and recognized or certified for their intended usage.

4.3.11 When necessary to avoid risks to health or safety, the manufacturer shall include in the product's technical documentation requirements for decommissioning and disposal of the hydrogen generator or its materials and components. The manufacturer is recommended to verify compliance with applicable regional or national environmental codes and standards; and to consider methods for recycling. Guidance to account for recycling is provided in Appendix 3.

4.3.12 Components in which condensation or other sources of any liquid may collect prior to start up or during normal operation shall be equipped with adequate means to safely relieve pressure if the potential exists for thermal energy to evaporate the said liquid.

4.3.13 The maximum temperatures of components and materials, as installed in the hydrogen generator, shall not exceed their temperature ratings.

4.3.14 The manufacturer shall give consideration to the suitability of the hydrogen generator to operate where contaminants (e.g. dust, salt, smoke, and corrosive gases) are present in the physical environment.

4.3.15 Any areas requiring access for production, adjustment and maintenance operations shall be designed and equipped to allow safe entry or access.

4.4 Selection of materials

4.4.1 When materials used to construct the hydrogen generator are known to pose health or physical hazards under certain circumstances, the manufacturer shall implement the measures and include in the product's technical documentation the requirements and information necessary to avoid endangering persons' safety or health.

4.4.2 Metallic and non-metallic materials used to construct internal or external parts of the hydrogen generator, in particular those exposed directly or indirectly to moisture or that contain process gas or liquid streams as well as all parts and materials used to seal or interconnect the same, e.g. welding consumables, shall be suitable for all physical, chemical and thermal conditions which are reasonably foreseeable within the scheduled lifetime of the equipment and for all test conditions; in particular:

- they shall retain their mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of service conditions and lifetime as specified by the manufacturer,

- they shall be sufficiently resistant to the chemical and physical action of the fluids that they contain and to environmental degradation; the chemical and physical properties necessary for operational safety shall not be significantly affected within the scheduled lifetime of the equipment unless replacement is foreseen; specifically, when selecting materials and manufacturing methods, due account shall be taken of the material's corrosion and wear resistance, electrical conductivity, impact strength, aging resistance, the effects of temperature variations, the effects of ultraviolet radiation, the effects arising when dissimilar materials are put together (e.g. galvanic corrosion), and resistance to carburisation attack and to the degradation effects of hydrogen on a material's mechanical performance. Guidance to account for carburisation attack and the degradation effects of hydrogen on a material's mechanical performance can be found in ISO TR 15916 and Appendix 2.

4.4.3 Where conditions of erosion, abrasion, corrosion, or other chemical attack or temperature degradation exist, as determined by the safety and reliability analysis (see Section 4.2), adequate measures shall be taken to:

- minimize that effect by appropriate design, e.g. additional thickness, or by appropriate protection, e.g. use of liners, cladding materials or surface coatings, taking due account of the intended and reasonably foreseeable use,

- permit replacement of parts which are most affected,

- draw attention, in the instructions referred to in 6.4.5, to type and frequency of inspection and maintenance measures necessary for continued safe use; where appropriate, it shall be indicated which parts are subject to wear and the criteria for replacement.

4.4.4 The manufacturer shall demonstrate that materials used for the construction of components containing combustible gases, in particular hydrogen, are sufficiently non-permeable. The permeability to hydrogen (and to other combustible gases non-soluble in water) of rubber, plastic hoses and hose assemblies shall be tested as per ISO 4080.

4.4.5 Plastic or elastomeric materials shall only be used in non-classified areas or Zone 2 locations as per IEC 60079-10. Plastic or elastomeric materials used in Zone 2 locations shall be conductive to avoid static buildup if conveying dry gases. Materials must have a maximum resistance of 1 mega ohm when tested in compliance with IEC 61340-2-1. See also 4.6.

4.5 Pressure equipment and piping

4.5.1 Pressure Equipment

Pressurized vessels, such as reactors, heat exchangers, gas-fired tube heaters and boilers, electric boilers, coolers, accumulators and similar containers, and associated pressure relief mechanisms, such as relief valves and similar devices, shall be constructed and marked in accordance with the applicable regional or national pressure equipment codes and standards.

Vessels that in accordance with the applicable regional or national pressure equipment codes and standards do not qualify as “pressure vessels”, such as tanks and similar containers, shall be constructed of suitable materials in accordance with Section 4.4 and shall meet applicable requirements of Section 4.3. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

4.5.2 Piping Systems

The provisions of this section apply to all piping systems used as part of the hydrogen generator including interconnection piping if this has been defined to be a hydrogen generator component.

The manufacturer shall specify in the product’s technical documentation the connections, piping materials, construction, testing requirements and other applicable limitations for the interconnection piping that has been defined to be part of the hydrogen generator. This refers in particular to the venting system or the interconnection piping used to deliver the gaseous hydrogen containing product stream to distributed components that may or may not be factory matched.

Metallic, non-metallic, rigid and flexible piping and its associated joints and fittings shall conform to the applicable sections of ISO 15649.

Piping systems designed for internal gage pressure at or above zero but less than 105 kPa, handling fluids that are non-flammable, non-toxic and not damaging to human tissue and having a design temperature from -29°C through 186°C are not included in the scope of ISO 15649. Piping systems under these conditions shall be constructed of suitable materials in accordance with Section 4.4 and shall meet applicable requirements of Section 4.3. Such pipes, and their related joints and fittings, shall be designed and constructed with adequate strength and leakage resistance to prevent unintended releases.

The design and construction of both rigid and flexible pipes and fittings shall consider the following aspects:

a) Materials shall meet the requirements specified in Section 4.4.

b) The internal surfaces of piping shall be thoroughly cleaned to remove loose particles, and the ends of piping shall be carefully reamed to remove obstructions and burrs.

c) If fluid condensate or sediment accumulation inside gaseous fluid piping could cause damage from water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions during start-up, shutdown and/or use, the manufacturer shall provide means for drainage and removal of deposits from low areas and for access during cleaning, inspection and maintenance. In particular, the manufacturer shall take measures to ensure against sediment or condensate accumulation in fuel gas controls. Sediment traps or filters shall be installed or adequate guidelines shall be provided in the product’s technical documentation. See also 4.3.12.

d) The manufacturer shall take measures to ensure against sediment accumulation in liquid fuel controls. A filter shall be provided upstream of the fuel controls.

e) Non-metallic piping used to convey combustible gases shall be protected against the possibility of overheating. Measures as required by the safety and reliability analysis specified in 4.1.2 shall be provided to prevent the temperature of components conveying combustible gases from surpassing their design temperatures.

4.5.2.1 Flue gas venting systems

The hydrogen generator shall be provided with a vent system that will convey products of combustion from fuel utilization equipment to the outside atmosphere. The manufacturer shall design and construct the vent pipe, or provide in the product’s technical documentation instructions to design and construct the vent pipe, in compliance with the following requirements:

a) Materials shall meet the requirements specified in Section 4.4. In particular, the venting system shall be constructed of material resistant to corrosion by condensate. Non-metallic material shall be judged on its temperature limitation, strength and resistance to the action of condensate.

b) The venting system parts of a hydrogen generator shall be rigidly constructed and durable as per the following requirements and tests specified in Section 5.9.

- Venting system parts, including parts within the hydrogen generator, shall not break, disassemble or become damaged to the extent that they permit unsafe hydrogen generator operation, when subjected to a longitudinal force of 223 N and a torque of 34 N-m.
- The vent terminal(s) shall be sufficiently rigid in construction and supported so it shall withstand a load of 68 kg without impairing damage or alteration of its position with respect to the hydrogen generator.
- A vent terminal shall be rigidly constructed so as not become damaged to the point where the appliance's operation is unacceptable when subjected to a 12 kg impact.

c) The vent pipe shall be properly supported and shall be provided with a rain cap or other feature that would not limit or obstruct the gas flow from venting vertically upward.

d) A means, such as drainage, shall be provided to prevent water, ice and other debris from accumulating inside the vent pipe or obstructing the vent pipe.

e) Vent pipe exhausts shall be located outdoors in a safe location, away from user areas, ignition sources, air intakes, building openings and overhangs.

f) A venting system for a hydrogen generator shall be leak tight.

g) A venting system for a hydrogen generator shall be watertight.

h) Where the exhaust gas passageway extends through a negative pressure zone within the hydrogen generator the connection to the vent connector shall be located entirely outside the negative pressure zone. This would include the extension of the zone by the use of a sealing collar. Annular stops, or the equivalent means, shall be provided to prevent penetration of the pipe into the negative pressure zone.

i) The exhaust outlet collar shall be of such size as to accommodate a vent connector of standard diameter that is commercially available, or to accommodate a conduit as specified in the manufacturers' installation instructions.

j) Pressure switches used to prove exhaust gas flow shall be factory set. The adjustment means shall then be factory locked. A pressure switch shall bear a marking indicating clearly the appliance manufacturers' or distributors' part number which correlates to the factory locked pressure setting.

k) Parts of a pressure switch in contact with exhaust gas condensate shall be corrosion resistant to exhaust gas condensate at the normal operating temperatures.

l) The hydrogen generator shall be capable of starting up and shall not shutdown when the vent system is exposed to a 100 Pa static pressure or 120 Pa velocity pressure (50 km/h wind velocity) as per tests in Section 5.13.4.

m) When the hydrogen generator is provided with a venting system, the average temperature of the exhaust gases conveyed by that venting system shall not exceed temperatures acceptable for the materials used to construct the venting system.

4.5.2.2 Pressure relief vent piping

A vent pipe that will divert the gas or vapour flow to the outside atmosphere shall be installed on pressurized components of the hydrogen generator for purging operations or for the purpose of relieving overpressure conditions. The manufacturer shall design and construct the vent pipe, or provide in the product's technical documentation instructions to design and construct the vent pipe, in compliance with the following requirements:

a) Materials shall meet the requirements specified in Section 4.4.

b) Piping and its associated joints and fittings shall be designed and constructed in conformance to ISO 15649 for the rated pressure, volume and temperature.

c) Pressure relief valves shall be designed and utilized in accordance with the applicable regional or national pressure equipment codes and standards or as per ISO 4216-1 or ISO4126-2, as applicable.

d) The vent pipe shall be properly supported and shall be provided with a rain cap or other feature that would not limit or obstruct the gas flow from venting vertically upward.

e) A means, such as drainage, shall be provided to prevent water, ice and other debris from accumulating inside the vent pipe or obstructing the vent pipe.

f) When required by the safety and reliability analysis defined in Section 4.1.2, at the connection fitting of the vent pipe and the pressurized flammable gas container, the manufacturer shall provide a bi-directional detonation flame arrester that is certified for the application.

g) Vent pipe exhausts shall be located outdoors in a safe location, away from user areas, ignition sources, air intakes, building openings and overhangs.

h) The minimum distance of the vent pipe exhaust to adjacent structures or equipment shall be 5m.

i) The minimum height of the vent pipe exhaust above any structure or equipment within a distance of 6m shall be 3m, or 2m above rooftops.

4.5.2.3 Product delivery piping

The hydrogen generator may include the interconnection piping used to deliver the gaseous hydrogen containing product stream to distributed components that may or may not be factory matched, e.g. a fuel cell power system or a hydrogen compression, storage and delivery system. The manufacturer shall design, construct and install the product delivery piping, or provide in the product's technical documentation instructions to design, construct and install the product delivery piping, in compliance with the following requirements:

a) Materials shall meet the requirements specified in Section 4.4. In particular the product delivery piping shall be constructed of material:

  - suitable for hydrogen service, non-permeable and resistant to the effects of hydrogen on the material's mechanical performance,
  - resistant to corrosion by condensate; non-metallic material shall be judged on its temperature limitation, strength and resistance to the action of condensate,

b) The product delivery piping and its associated joints and fittings shall be designed, constructed and tested in conformance to ISO 15649 for the rated pressure, volume and temperature.

c) The product delivery piping shall be designed and constructed to provide allowance for expansion, contraction, vibration, settlement and fire exposure.

d) The product delivery piping shall be marked "HYDROGEN" at intervals not exceeding 3m. Letters of such marking shall be in color other than the color of the piping. Piping shall be marked a minimum of one time in each room or space through which it extends.

e) The product delivery piping shall be designed, constructed and installed such as to prevent the occurrence of a hydrogen release and that a hydrogen release develops into a hazardous situation. For that purpose:

- the product delivery piping shall not be installed in or through conduits that could disperse hydrogen releases to ignition sources, e.g. a circulating air duct, clothes chute, chimney or gas vent, ventilating duct, dumbwaiter or elevator shaft,

- portions of product delivery piping installed in concealed locations shall not be located in solid partitions and solid walls, except when installed in a ventilated chase or casing; and shall not have unions, tubing fittings, right or left couplings, bushings, compression couplings and swing joints made by combinations of fittings; exceptions are the joining of tubing by brazing and the use of fittings specifically tested and certified for use in concealed locations,

f) The product delivery piping shall be protected against physical damage. Means shall be provided to prevent excessive stressing of the product delivery piping e.g. where there is heavy vehicular traffic or where soil conditions are unstable and settling of piping or foundation walls could occur. For that purpose:

- where product delivery piping is subject to excessive moisture or corrosive substances, the piping shall be protected in an adequate manner; when dissimilar metals are joined underground, an insulating coupling or fitting shall be used; the piping shall not be laid in contact with cinders; uncoated threaded or socket welded joints shall not be used in piping in contact with soil or where internal or external crevice corrosion is known to occur,

- product delivery piping installed underground shall not penetrate the outer foundation or basement of a building, and shall be installed with sufficient clearance from other underground structures to avoid contact therewith, to allow maintenance, and to protect against damage from proximity to other structures,

- in concealed locations, where piping is installed through holes or notches in wood studs, joists, rafters or similar members, the pipe shall be protected by adequate means such as shield plates,

- product delivery piping in solid floors shall be laid in channels in the floor and covered in a manner to allow access to the piping with a minimum amount of damage to the installation; as an alternative to installation in channels, the piping shall be installed in a tightly sealing metallic or plastic casing ventilated to the outdoors.

- product delivery piping installed above ground, outdoors, shall be securely supported and located where it will be protected from physical damage; piping passing through an exterior wall shall be adequately protected, e.g. by means of encasing it in a protective piping sleeve; it shall also be protected against corrosion by coating or wrapping in an inert material.

- product delivery piping passing through interior concrete or masonry walls shall be protected against differential settlement.

4.5.4 Heat Exchangers

When internal to the hydrogen generator and not capable of affecting the potable water supply, any means of heat transfer, commensurate with the chemistry of the affected fluids or gases is acceptable. See also Section 4.5.1.

When between the hydrogen generator and other external services and capable of affecting the potable water supply system or vessels such as heat exchangers and similar containers, such vessels shall be of double-wall construction when handling toxic coolants. (see Section 3, Definitions). An air gap, open to the atmosphere, shall be provided between the two walls. Single wall separation is acceptable when the pressure of the toxic fluid is at least 68.9 kPa lower than the pressure on the potable water side and such side is protected with a pressure gradient monitor (see Section 3, Definitions), or the coolant is non-toxic (see Section 3, Definitions).

4.6 Protection against fire or explosion hazards

The hydrogen generator shall be designed and constructed to avoid any credible risk of fire or explosion posed by the hydrogen generator itself or by gases, liquids, dust, vapours or other substances produced or used by the hydrogen generator.

4.6.1 Prevention of fire and explosion hazards in the vicinity of hydrogen generators provided with cabinets

Hydrogen generators provided with cabinets shall not release to their surrounding environments flammable liquids or concentrations of flammable gases or vapours that would cause the location where they are installed to be classified as hazardous according to IEC 60079-10.

4.6.1.1 Negative pressure ventilation

Hydrogen generator compartments with sources of flammable gas or vapour shall be mechanically ventilated at negative pressure relative to other compartments and their surroundings. Failure of ventilation, confirmed by measuring either flow or pressure, shall cause a hydrogen generator shutdown.

4.6.1.2 Non-hazardous release of flammable substances

a) Hydrogen generators provided with a cabinet shall be designed so that the maximum concentration of any flammable gas in the hydrogen generator ventilation exhaust remains below 25-percent of the LEL of that gas (LFL for hydrogen).

b) The minimum ventilation flow shall be set such that for the release rate of flammable gases or vapours from the hydrogen generator, as determined per leakage test specified in Section 5.5, the maximum concentration of flammables in the ventilation exhaust remains below 25-percent of the LEL (LFL for hydrogen).

c) The hydrogen generator shall be provided with passive and active means, or a combination thereof, to avoid the occurrence of releases of flammable gases or vapours at a rate that cannot be diluted by the mechanical ventilation to levels below 25-percent of the LEL (LFL for hydrogen). Sudden and catastrophic failures need not to be considered a release scenario in this analysis when protection against such failures has already been contemplated in the vessel and piping design (see also Section 4.5).

Passive means may include the mechanical limitation of releases of flammable gases or vapours to a maximum value by using pipe orifices and similar methods of flow restriction or joints permanently secured and so constructed that they limit the release rate to a predictable maximum value.

Active means may include flow measurements and controls or the provision of safety devices such as combustible gas sensors. These means shall meet the requirements specified in Section 4.9 and shall cause a hydrogen generator shutdown upon occurrence of conditions under which the concentration of any flammable gas in the ventilation exhaust exceeds 25-percent of the LEL of that gas (LFL for hydrogen).

d) The hydrogen generator shall be designed for the safe dispersal of the ventilation and process exhaust streams. In particular, for indoor installations the ventilation and process exhaust shall be designed for connection to a flue or venting system as per Section 4.5.2.1.

e) Liquid fueled hydrogen generators shall include provisions for capturing, recycling, or safe disposal of released liquid fuel. Drip pans, spill guards, or double-walled pipe shall be designed to prevent uncontrolled releases.

4.6.1.3 Emergency venting of flammable gases

Pressurized hydrogen generators or components thereof shall be protected by pressure-relieving devices and equipped with venting to relieve excessive internal pressure as per Section 4.5.2.2. Hydrogen generators shall not discharge inside buildings.

4.6.2 Prevention of fire and explosion hazards within hydrogen generator cabinets

a) Hydrogen generator cabinets shall be designed, and the product's technical documentation shall provide operation and maintenance information, so that any releases of flammable liquids, gases or vapours within hydrogen generator cabinets, and consequently the extent of hazardous areas in their interior, are kept to a minimum, whether in operation or otherwise, with regard to frequency, duration and quantity.

b) Within hydrogen generator cabinets, compartments with sources of flammable gas or vapour shall be classified and the extent of hazardous areas determined according to IEC 60079-10, taking due account of the likely frequency and duration of release, the release rate, release material physical properties, ventilation, system geometry and other relevant factors.

c) Within areas classified as hazardous the manufacturer shall eliminate ignition sources by ensuring that:

- the installed electrical equipment is suitable for the area classification according to IEC 60079-10,
- the installed electrical resistance trace heating, if available, complies with IEC 62086-1.
- the surface temperatures do not exceed 80% of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas or vapour. See IEC 60079-20 for guidance regarding auto-ignition temperatures of various flammable fluids,
- the potential for static discharge has been eliminated by proper bonding and grounding as per IEC 60204-1, and by proper material selection as per 4.4.5.
- equipment containing materials capable of catalysing the reaction of flammable fluids with air shall be capable of suppressing the propagation of the reaction from the equipment to the surrounding flammable atmosphere.

d) When the provided negative pressure ventilation influences the type of area classification, that area shall be purged with a minimum of 5 air changes prior to energizing any devices not suitable for the non-ventilated area classification. All devices, which must be energized prior to purging or in order to accomplish purging, must be suitable for the non-ventilated area classification. Purging is not required if the atmosphere within the compartment and associated ducts can be demonstrated by design to be non-hazardous.

e) Within hydrogen generator cabinets, compartments that contain electrical or mechanical equipment shall be maintained at positive pressure relative to adjacent compartments with sources of flammable gas or vapour, unless the equipment is suitable for the area classification according to IEC 60079-10.

f) The manufacturer shall provide in the product's technical documentation instructions to ensure that all equipment affecting the area classification, when it has been subjected to maintenance, is carefully checked during and after re-assembly to ensure that the integrity of the original design, as it affects safety, has been maintained before it is returned to service.

4.6.3 Prevention of fire and explosion hazards in the vicinity of hydrogen generators without cabinets

a) Outdoor hydrogen generators without cabinets are potentially sources of flammable gas or vapour. They shall be designed, and the product's technical documentation shall provide operation and maintenance information, so that any releases of flammable liquids, gases or vapours from a hydrogen generator, and consequently the extent of hazardous areas in its vicinity, are kept to a minimum, whether in operation or otherwise, with regard to frequency, duration and quantity.

b). All locations in the vicinity of outdoor hydrogen generators without cabinets shall be classified and the extent of hazardous areas determined according to IEC 60079-10, taking due account of the likely frequency and duration of release, the release rate, release material physical properties, ventilation, system geometry and other relevant factors.

c) Within areas classified as hazardous the manufacturer shall eliminate ignition sources by ensuring that:

- the installed electrical equipment is suitable for the area classification according to IEC 60079-10, ,
- the installed electrical resistance trace heating, if available, complies with IEC 62086-1.

• the surface temperatures do not exceed 80% of the auto-ignition temperature, expressed in degrees Celsius, of the flammable gas or vapour. See IEC 60079-20 for guidance regarding auto-ignition temperatures of various flammable fluids,

• the potential for static discharge has been eliminated by proper bonding and grounding as per IEC 60204-1, and by proper material selection as per 4.4.5.

• equipment containing materials capable of catalysing the reaction of flammable fluids with air shall be capable of suppressing the propagation of the reaction from the equipment to the surrounding flammable atmosphere.

d) When mechanical ventilation is used to influence the type of area classification, that area shall be purged prior to energizing any devices not suitable for the non-ventilated area classification. This purge shall be determined by analysis based on flow characteristics and system geometry. All devices, which must be energized prior to purging or in order to accomplish purging, must be suitable for the non-ventilated area classification. Purging is not required if the atmosphere in that area can be demonstrated by design to be non-hazardous.

e) In the vicinity of outdoor hydrogen generators without cabinets, compartments that contain electrical or mechanical equipment shall be positive pressure ventilated with fresh air as per IEC 60079-2, unless the equipment is suitable for the area classification according to IEC 60079-10.

f) The manufacturer shall provide in the product's technical documentation instructions to ensure that all equipment affecting the area classification, when it has been subjected to maintenance, is carefully checked during and after re-assembly to ensure that the integrity of the original design, as it affects safety, has been maintained before it is returned to service.

g) The manufacturer shall include in the product's technical documentation the information, requirements and other applicable limitations to install and operate hydrogen generators without cabinets such as to avoid risks to health or safety.

4.6.4 Prevention of fire and explosion hazards in burners

a) Hydrogen generators shall be designed such that the unsafe build up of flammable or explosive gases in burners (start, main and auxiliary burners of a reformer section, tail gas burners) is avoided.

b) The main burner shall be fitted with a pilot or a device for direct ignition.

c) The direct ignition device shall be controlled automatically and shall not cause deterioration of the burner. Direct ignition devices shall be positively positioned with respect to the main burner ports. Means shall be provided to prevent incorrect assembly or reversible mounting of any direct ignition device in relation to the burner being served.

d) Pilots shall be controlled automatically and direct ignition shall light any pilot fuel. Pilots shall be designed and fitted in such a way that they are located correctly in relation to the burners that they ignite. When a pilot is an integral part of the start burner, it need be evaluated only under the construction and performance specifications of this standard.

e) Automatic electrical burner control systems shall comply with requirements specified in Section 4.9.2.

f) The main burner or pilot flame, or both, shall be supervised by a flame detector. If a main burner is ignited by a pilot, the presence of flame at the pilot shall be detected before gas is released to the main burner. A system having an interrupted pilot shall provide supervision of the main burner flame following the main burner flame-establishing period.

g) Pilot flame supervision shall be only at a point where the pilot will effectively ignite fuel at the main burner even when the fuel supply to the pilot is reduced so the flame is just sufficient to actuate the primary safety control.

h) If the heat input of a pilot does not exceed 0.250 kW, there is no requirement for the flame establishing period.

i) If the heat input of a pilot exceeds 0.250 kW, or in case of direct ignition of the main burner, the flame establishing period is determined by the manufacturer so that in accordance with the delayed ignition test (Section 5.8.1) no health or safety hazard for the user or damage to the hydrogen generator occurs.

j) Each pilot or direct main burner ignition attempt begins with the opening of the fuel valves and ends with the closing of the fuel valves. The spark shall continue at least until ignition occurs or until the end of the flame establishing period.

k) Pilot or direct main burner ignition shall be attempted a maximum of 3 times, each time followed by purging. An absence of flame at the end of the 3rd attempt shall result in, at least, a volatile lockout.

l) In case of flame failure, the system shall cause at least re-ignition, recycling or volatile lockout.

m) The pilot or main burner flame failure lock-out time shall not exceed 3s.

n) If re-ignition takes place, under the test conditions of 5.8.1*,* the direct ignition device shall be re-energized within a maximum time of 1s after the disappearance of a flame signal. In this case the flame establishing period is the same as is used for ignition and starts when the ignition device is energized. An absence of flame at the end of the flame establishing period shall result in, at least, volatile lockout.

o) If recycling takes place, under the test conditions of 5.8.1*,* this shall be preceded by an interruption of the gas supply and purging; the ignition sequence shall restart from the beginning. In this case the flame establishing period is the same as is used for ignition and starts when the ignition device is energized. Recycling shall be attempted a maximum of 3 times, each time followed by purging. An absence of flame at the end of the 3rd attempt shall result in, at least, a volatile lockout.

p) A burner circuit shall be arranged to prevent feedback by a motor, capacitor or similar device from energizing a fuel valve or ignition device after a control functions to shut off the main burner.

q) When for safety reasons a passive state is required prior to startup or after shutdown, means shall be provided to automatically purge a burner housing or enclosure of any flammable gas mixture before the trial for ignition at the start and in-between recycling trials. This purge shall provide a minimum of four air changes in the compartment.

r) Ignition system components shall be installed so the operation of these devices and main burner ignition will not be affected by falling particles during normal operation.

s) When primary air under pressure is mixed with the fuel supply, effective means shall be provided to prevent air from passing back into the fuel line, or fuel into the air supply. The fuel and air supply shall be suitably controlled to prove air flow prior to ignition and to prevent fuel from entering each reformer burner until the air supply is available and, in the event of air fan failure, to shut off the fuel supply.

t) Linkage for operating the fuel and air controls, if used, shall be designed to reliably maintain the correct fuel-air ratio and to resist accidental breakage and disengagement.

u) Upon shutdown, hazardous gases in the process system shall be safely contained or disposed.

v) Where air and fuel or combustible process gas streams are put in close contact as part of the thermal management system, the manufacturer shall provide the hydrogen generator with adequate means to prevent that health or safety risks arise from the crossing of air into fuel or combustible process gas lines or of fuel or combustible process gas into air lines.

w) The hydrogen generator exhaust to atmosphere, under a blocked outlet condition, shall not contain concentrations of carbon monoxide in excess of 300 ppm in an air-free sample of the effluents as per test in Section 5.13.2. Additionally, the hydrogen generator shall not produce a carbon monoxide concentration in excess of 300 ppm in air-free sample of the effluents when the air supply inlet is blocked as per test in Section 5.13.3.

4.6.5 Prevention of fire and explosion hazards in catalytic fuel oxidation systems (catalytic burners)

a) Within hydrogen generator components carrying fluids, in which flammable or explosive gas volumes are intentionally produced to conduct a controlled catalytic fuel oxidation reaction (e.g. catalytic partial oxidation, catalytic combustion), the manufacturer shall avoid the unsafe build up of flammable or explosive gases.

b) When for safety reasons a passive state is required prior to startup or after shutdown, means shall be provided to purge the catalytic fuel oxidation system components. The purging system may utilize a medium specified by the manufacturer such as but not limited to nitrogen, air or steam. The extent of purging is determined by considering flow characteristics, system dynamics and geometry.

c) Where air is mixed with fuel, the manufacturer shall provide adequate means to prevent that air flows back into the fuel line, or fuel into the air supply.

1. For air-rich systems.

   The fuel and air supply shall be suitably controlled to prove air prior to reaction initiation, and to prevent fuel from entering the reactor until the air supply is available.

2. For fuel-rich systems.

   The fuel and air supply shall be suitably controlled to prove fuel prior to reaction initiation, and to prevent air from entering the reactor until the fuel is available.

e) Linkage for operating the fuel and air controls, if used, shall be designed to reliably maintain the correct fuel-air ratio and to resist accidental breakage and disengagement.

f) The reaction initiation time shall be determined by considering the response time of the system control devices and the time required to build up the maximum allowable quantity of flammable or explosive mixture that can safely be contained in the system based on flow rates, fuel-air mixture flammability, and system dynamics and geometry.

g) If the catalytic reaction is not established within the reaction initiation time, the system shall automatically shut off the fuel supply, or for fuel-rich operations, the supply of all reactants.

h) The temperature of the catalyst shall be monitored either directly or indirectly. The reaction fails if the temperature or rate of temperature change of the catalyst fall outside an acceptable range. Then the system shall automatically shut off the fuel supply, or for fuel-rich operations, the supply of all reactants. The reaction failure lock-out time shall not exceed 3s

i) If a mixture of fuel and air could potentially build up inside the hydrogen generator following either the failure of a reaction to start within the reaction initiation time; or the extinction of a reaction; or decrease or increase of the reaction rate to unsafe levels, the manufacturer shall ensure that the maximum quantity of flammable mixture that could credibly accumulate, if combusted, produces pressures and temperatures that can be contained within the components exposed to such conditions.

j) Upon shutdown, hazardous gases in the process system shall be safely contained or disposed.

k) Where air and fuel streams are put in close contact as part of the thermal management system, the manufacturer shall provide the hydrogen generator with adequate means to prevent that health or safety risks arise from the crossing of air into fuel lines or of fuel into air lines.

4.7 Protection against electrical hazards

The manufacturer shall ensure that the electric system design and construction as well as the application of electric and electronic equipment, including electric motors and electric enclosures, meet the requirements of IEC 60204-1 or IEC 60335-1 as applicable.

Electrical components installed in outdoor hydrogen generators without cabinets shall be adequately protected from rain. Suitability of protection shall be demonstrated as per IEC 60529. The protection shall have a minimum rating of IPX4 as per IEC 60529.

The type of converter for motor speed control shall be suitable for the application as per IEC 60146-1-1.

Electric motors and their associated couplings, belts and pulleys shall be so mounted that they are adequately protected and are easily accessible for inspection, maintenance, adjustment and alignment, lubrication and replacement.

Electrical clearance (through air) and creepage (over surface) distances as well as solid insulation thickness for electrical circuits, shall be in accordance with Section 20 of IEC 60730-1.

4.8 Electromagnetic compatibility (EMC)

The hydrogen generator shall not generate electromagnetic disturbances above the levels appropriate for its intended places of use. In addition, the equipment shall have an adequate level of immunity to electromagnetic disturbances so that it can operate correctly in its intended environment. As applicable, the generator shall comply with the following standards:

IEC 61000-6-1	Electromagnetic compatibility - Part 6-1: Generic standards - Immunity for residential, commercial and light industrial environments
IEC 61000-6-2	Electromagnetic compatibility – Part 6-2: Generic standard – Immunity for industrial environments
IEC 61000-6-3	Electromagnetic compatibility - Part 6-3: Generic standards - Emission standard for residential, commercial and light industrial environments
IEC 61000-6-4	Electromagnetic compatibility – Part 6-4: Generic standard – Emission standard for industrial environments
IEC 61000-3-2	Electromagnetic compatibility (EMC) Part 3-2: Limits for harmonic currents emissions (equipment input current up to 16 A per phase)
IEC 61000-3-3	Electromagnetic compatibility (EMC) Part 3-3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current up to 16 A.
IEC 61000-3-4	Electromagnetic compatibility (EMC) Part 3-4: Limits – Limitation of emission of harmonic currents emissions in low-voltage power supply systems for equipment with rated current greater than 16 A
IEC 61000-3-5	Electromagnetic compatibility (EMC) Part 3-5: Limits - Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current greater then 16 A.

4.9 Control systems and protective/safety components

4.9.1 General requirements

4.9.1.1 The safety and reliability analysis as specified in 4.1.2 shall provide the basis to set the protection parameters of the safety circuit.

4.9.1.2. The hydrogen generator shall be designed such that the single failure of a component does not cascade into a hazardous condition. Means to prevent cascade failures include but are not limited to:

- protective devices in the generator (e.g. interlocking guards, trip devices);
- protective interlocking of the electrical circuit;
- use of proven techniques and components;
- provision of partial or complete redundancy or diversity;
- provision for functional tests.

Guidelines for the design of electrical, electronic and programmable controls can be found in IEC 61061 or IEC 61511-1.

4.9.2 Control Systems and Operation

Automatic electrical and electronic controls of hydrogen generators shall be designed and constructed so that they are safe and reliable. Residential, commercial and light industrial hydrogen generators shall conform to IEC 60730-1. industrial hydrogen generators shall conform to IEC 61511-1.

Automatic electrical burner control systems shall comply with IEC 60730-2-5.

Automatic electrical control systems for catalytic oxidation reactors shall comply as applicable with IEC 60730-2-5. Specific requirements are provided in 4.6.3.

Manual controls shall be clearly marked and designed to prevent inadvertent adjustment and activation.

4.9.2.1 Start

The start of an operation shall be possible only when all the safeguards are in place and are functional. Suitable interlocks shall be provided to secure correct sequential starting.

It shall be possible for automated plant functioning in automatic mode to be restarted after a stoppage once the safety conditions have been fulfilled. It shall also be possible to restart the hydrogen generator by intentional actuation of a control provided for the purpose, provided such restarting is verifiably non-hazardous. This requirement does not apply to the restarting of the hydrogen generator resulting from the normal sequence of an automatic cycle.

4.9.2.2 Shutdowns

As determined by the reliability assessment indicated in 4.1.2 and the functional requirements of the hydrogen generator, the hydrogen generator shall be provided with the following shutdowns:

- Safety shutdowns

A safety shutdown is, for air-rich operation, the de-energization of the main fuel flow means, or for fuel-rich operation, the de-energization of both the process air flow and the main fuel flow means, as the result of the action of a limiter, a cut-out or the detection of an internal fault of the system.

- Controlled shutdown

A controlled shutdown is, for air-rich operation, the de-energization of the main fuel flow means, or for fuel-rich operation, the de-energization of both the process air flow and the main fuel flow means, as the result of the opening of a control loop by a control device such as a thermostat. The system returns to the start position.

4.9.2.2.1 Safety shutdowns

a. General:

Safety shutdowns shall be fitted to the hydrogen generator in order to avert actual or impending danger that cannot be corrected by controls. These functions shall:

- remove all power to the equipment and stop the dangerous condition without creating additional hazards
- trigger or permit the triggering of certain safeguard actions where necessary
- override all other functions and operations in all modes;
- prevent reset from initiating a restart
- be fitted with restart lock-outs such that a new start command may take effect on normal operation only after the restart lock-outs have been intentionally reset

b. Emergency stop:

Manual safety shutdowns (i.e. emergency stops) shall have clearly identifiable, clearly visible and quickly accessible controls such as buttons, in accordance with ISO 13850 (see also 4.9.5).

c. Control functions in the event of control systems failure:

In case of fault in the control system logic, or failure of or damage to the control system hardware:

- the hydrogen generator shall not be prevented from stopping once the stop command has been given,
- automatic or manual stopping of the moving parts shall be unimpeded,
- the protection devices shall remain fully effective.
- the hydrogen generator shall not restart unexpectedly,

When protective device or interlock causes a safety shutdown of the generator, that condition shall be signalled to the logic of the control system. The reset of the shutdown function shall not initiate any hazardous condition.

Control/monitoring systems that can operate safely in the hazardous situation may be left energized to provide system information.

4.9.2.2.2 Controlled shutdown

Upset conditions that can be safely controlled or that do not pose immediate danger may be corrected with a controlled shutdown. A controlled shutdown may remove all power to the equipment, or may leave power available to the generator actuators.

4.9.2.3 Permissives

Permissives shall be implemented consistent with requirements established from the safety and reliability analysis described in 4.1.2. A "permissive" is defined as a condition within a logic sequence that must be satisfied before the sequence is allowed to proceed to the next phase.

4.9.2.4 Complex installations

When the hydrogen generator is designed to work together with other equipment (e.g. as part of a fuel cell power system), the hydrogen generator stop controls, including the emergency stop, shall be provided with means, such as signal interfaces, to enable the coordinated shutdown with all equipment upstream and/or downstream of the hydrogen generator if continued operation can be dangerous.

4.9.2.5 Operating modes

a. There shall be two primary operating modes: On and Off.

During the On-mode the hydrogen generator components shall be active and operating as necessary to supply hydrogen. The following conditions are also considered on-modes:

- Idle (zero net hydrogen output)
- Automatic start enabled (power left available to the generator actuators)

In the Off-mode, all power to the hydrogen generator shall be cut and the unit shall be inactive.

b. There shall be two primary transitions: start-up and shutdown

Start-up is the automatic transition from OFF to On and shall be initiated from an external signal.

Shutdown is the automatic transition from On to OFF. It may be initiated either via an external signal, or internal signal in response to out of limits conditions to the hydrogen generator controller.

c. Secondary operating modes and transitions may be provided as necessary, such as to allow for different hydrogen production rates or for adjustment, maintenance, or inspection activities.

d. Mode selection

If the hydrogen generator has been designed and built to allow for its use in several control or operating modes presenting different safety levels (e.g. to allow for adjustment, maintenance, inspection, etc.), it shall be capable of mode selection that can be secured in each position. Each position of the selector shall correspond to a single operating or control mode and shall be fitted with restart lockouts. A new start command may take effect on normal operation only after the restart lockouts have been intentionally reset.

Mode selection shall be allowed by any securable means, such as a positioning knob, key lock, or software command, to prevent unintentional change to a different mode that may lead to a hazardous condition.

The selector may be designed to restrict user access to certain hydrogen generator operating modes (e.g. access codes for certain numerically controlled functions, etc.).

The mode selected shall override all other control systems with the exception of the safety shutdowns.

4.9.2.6 Remote monitoring and control systems

Hydrogen generators that can be operated remotely shall have a local, labelled switch or other means to disconnect the generator from remote signals that may be used while a local operator performs inspection or maintenance. Remote monitoring and control systems shall:

a. Be allowed on hydrogen generators only where remote control will not lead to an unsafe condition;

b. Not override locally set manual controls;

c. Not override protective safety controls.

Procedures to address changes to the remote monitoring system shall be provided as per section 6.4.4.

4.9.3 Protective/Safety Components

a) Suitable protective devices and combinations thereof comprise:

- safety devices
- where appropriate, adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the hydrogen generator within the allowable limits.

b) Safety devices shall:

- be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable,
- have their safety functions independent of other possible functions,
- comply with appropriate design principles in order to obtain suitable and reliable protection. These principles include, in particular, fail-safe modes, redundancy, diversity and self-diagnosis.

c) Dangerous overloading of equipment shall be prevented at the design stage by means of integrated measurement, regulation and control devices, such as over-current cut-off switches, temperature limiters, differential pressure switches, flowmeters, time-lag relays, overspeed monitors and/or similar types of monitoring devices.

d) Safety devices with a measuring function shall be designed and constructed so that they can cope with foreseeable operating requirements and special conditions of use. Where necessary, it shall be possible to check the reading accuracy and serviceability of devices. These devices shall incorporate a safety factor that ensures that the alarm threshold lies far enough outside the limits to be registered, taking into account, in particular, the operating conditions of the installation and possible aberrations in the measuring system.

e) Pressure limiting devices, such as pressure switches, shall be provided as per IEC 60730-2-6.

f) Temperature monitoring devices shall have an adequately safe response time, consistent with the measurement function, as per IEC 60730-2-9.

g) Gas sensors relied upon for safety shall comply with IEC 61179-4 and be selected, installed, used and maintained in accordance with IEC61179-6.

h) All parts of hydrogen generators which are set or adjusted at the stage of manufacture, and which should not be manipulated by the user or the installer, shall be appropriately protected.

i) Levers and other controlling and setting devices shall be clearly marked and given appropriate instructions so as to prevent any error in handling. Their design shall be such as to preclude accidental manipulation.

4.10 Pneumatic and hydraulic equipment

Pneumatic and hydraulic equipment of hydrogen generators shall be designed as per ISO 4414 and ISO 4413.

In particular, pneumatic and hydraulic equipment of hydrogen generators shall be so designed that:

- the maximum allowed pressure cannot be exceeded in the circuits (e.g. by means of pressure limiting devices),
- no hazards may result from pressure losses, pressure drops or losses of vacuum,
- no hazardous fluid jet may result from leakages or component failures,
- air receivers, fluid reservoirs or similar vessels (such as hydro-pneumatic accumulators) comply with the design rules of these elements (see section 4.5), all elements of the equipment, and specially pipes and hoses, be protected against harmful external effects,

- as far as possible, reservoirs and similar vessels (e.g. hydro-pneumatic accumulators) be automatically depressurized when isolating the hydrogen generator from its power supply and, if it is not possible, means be provided for their isolation and/or local depressurization and pressure indication,

- all elements which remain under pressure after isolation of the hydrogen generator from its power supply be provided with clearly identified exhaust devices, and a warning label drawing attention to the necessity of depressurizing those elements before setting or maintenance activity on the hydrogen generator.

4.11 Valves

4.11.1 General considerations

Valves shall be designed as per IEC 60534-1.

4.11.2 Shut-off valves

a) Shut-off valves shall be provided for all equipment and systems where containment or blockage of the process fluid flow is necessary during shutdown, testing, maintenance, upset or emergency conditions.

b) Shut-off valves shall be rated for the service pressure, temperature and fluid characteristics.

c) Actuators mounted on shut-off valves shall be temperature-rated to withstand heat conducted from the valve body.

d) Electrically, hydraulically or pneumatically operated shut-off valves shall be of a type that will move to a failsafe position upon loss of actuation energy.

4.11.3 Supply fuel valves

Supply fuel valves shall meet the following requirements:

a. All fuel supplied to the hydrogen generator shall pass through at least two automatic valves, in series, each of which serves as an operating valve and a safety shutoff valve.

b. Any fuel supplied directly to fuel-fired equipment, such as a startup boiler or a reformer start burner, shall also pass through at least two automatic valves, in series, each of which serves as an operating valve and a safety shutoff valve. These valves may or may not be contained in a single control body.

c. Electrically operated supply fuel valves shall meet the requirements of IEC 60730-2-17 or IEC 60730-2-19 as applicable.

d. When fuel gases are recycled from appliances using the hydrogen generator output gas, the connection may be exempt from employing shutoff valves if demonstrated to be safe as per the safety and reliability analysis of 4.1.2.

4.12 Rotating equipment

4.12.1 General requirements:

a) Rotating equipment shall be designed for the pressures, temperatures and fluids to which they may be subjected under normal operating conditions.

b) Fluid inlet and outlet lines shall be adequately protected from damage due to vibration.

c) Shaft seals shall be compatible with the pumped fluids and the operating temperatures and pressures expected in normal and abnormal operation and during normal and emergency shutdowns.

d) Shaft seals shall be designed such that hazardous fluid leakage is avoided. If shaft seals will leak hazardous fluids, the manufacturer shall provide hazardous fluid containment or dilution means as necessary to avoid risks to health or safety.

d) Motors, bearings, and seals shall be suitable for the expected duty cycles.

4.12.2 Compressors

4.12.2.1 Where appropriate, packaged compressors shall conform to one of the following standards:

Standard Number	**Application**
ISO 5388:1981	Stationary air compressors
ISO 10439:2002	Petroleum, chemical and gas service industries -- Centrifugal compressors
ISO 10442:2002	Petroleum, chemical and gas service industries -- Packaged, integrally geared centrifugal air compressors
ISO 13707:2000	Petroleum and natural gas industries -- Reciprocating compressors
ISO 10440-1:2000	Petroleum and natural gas industries -- Rotary-type positive-displacement compressors -- Part 1: Process compressors (oil-free)
ISO 10440-2:2001	Petroleum and natural gas industries -- Rotary-type positive-displacement compressors -- Part 2: Packaged air compressors (oil-free)
ISO 13631:2002	Petroleum and natural gas industries -- Packaged reciprocating gas compressors

4.12.2.2 Unless determined unnecessary by the safety and reliability analysis, compressors, or compressor systems, shall be provided with the following:

a) Pressure relief devices that limit each stage pressure to the maximum operating pressure for the compression cylinder and piping associated with that stage of compression.

b) An automatic shutdown control for high discharge and low suction pressure.

c) Where required to re-start the compressor after shutdown, an unloading device that captures and recycles blow down gas for re-use, and/or safe venting.

d) Vibration isolation from the inlet pipe to the compressor suction line.

e) A pressure limiting device to avoid over pressurization at the inlet.

4.12.2.3 Compressors excluded from the scope of the standards referenced in 4.12.2.1 due to small capacity or low discharge pressure need only to comply with the requirements specified in 4.12.2.2. Packaged low discharge pressure compressors (fans and blowers) shall be guarded as per ISO 12499 (see also Section 4.3.1).

4.12.3 Pumps

4.12.3.1 Packaged electric pumps for process liquids shall conform to ISO 13709-2 or ISO 14847. Packaged electric pumps for water shall conform to IEC 60335-2-41 or IEC 60335-2-51 as applicable.

4.12.3.2 Electric pumps, or electric pump systems, shall be provided with the following:

a) Pressure relief devices that limit both inlet and outlet pressure to less than the design pressure of the piping. If the shut-off head of the electric pump is less than the pressure rating of the piping, relief valves are not required. Relief valve releases shall be routed to a safe place.

b) An automatic shutdown control for high discharge pressure.

c) Suction and discharge lines shall be adequately protected from damage due to vibration.

4.12.3.3 Pumps excluded from the scope of the standards referenced in 4.12.3.1 due to small capacity or low discharge pressure need only to comply with the requirements specified in 4.12.3.2.

4.13 Cabinets

4.13.1 Hydrogen generator cabinets shall have sufficient strength, rigidity, durability, resistance to corrosion and other physical properties to support and protect all hydrogen generator components and piping; and to meet the requirements of storage, transport, installation, and final location conditions.

4.13.2 All parts of a hydrogen generator intended for use indoors shall be enclosed by a suitable containment structure, such as a cabinet, casing or jacket.

4.13.3 Hydrogen generator cabinets intended for use indoors or under conditions of weather-protected outdoor locations shall be designed and tested as to meet a minimum IP22 rating as per IEC 60529.

4.13.4 The hydrogen generator for use under conditions of non weather-protected outdoor locations shall start and operate normally, without damage or malfunctioning of any part that would create a hazardous condition when subjected to a simulated rain test per IEC 60529, Test Condition 14.2.4a.

4.13.5 Hydrogen generators cabinets shall be negative pressure ventilated as per 4.6.1.

4.13.6 A ventilation exhaust system shall be provided for proper ventilation, so that flammable gases do not accumulate within the containment structure. Ventilation openings shall be designed so that they will not become obstructed during normal operation either by dust, snow or vegetation in accordance with the expected application.

4.13.7 Where exhaust gases do not discharge directly to a safe outdoor location by means of the hydrogen generator exhaust system, a venting system shall be provided as per Section 4.5.2.1. The venting system shall be constructed of materials resistant to the temperature and anticipated chemical composition of the vent products and constructed to be airtight. Means shall also be provided to limit exhaust temperatures.

4.13.8 All materials used to construct cabinets, including joints or gaskets of doors, shall be capable of withstanding the physical, chemical and thermal conditions that are reasonably foreseeable throughout the hydrogen generator life.

4.13.9 Access panels, covers or insulation that need to be removed for normal servicing and accessibility shall be designed such that repeated removal and replacement will not cause damage or impair insulating value.

4.13.10 Access panels, covers or insulation that need to be removed for normal servicing and accessibility shall not be interchangeable if that interchange may lead to an unsafe condition.

4.13.11 Any access panel, cover or door that is intended to protect equipment from entry by users or untrained personnel shall have means for retaining it in place and shall require the use of a tool, key or similar mechanical means to open. For residential units, this shall include all access panels, covers, or doors.

4.13.12 All parts of hydrogen generators that are set or adjusted at the stage of manufacture and that should not be manipulated by the user or the installer shall be adequately protected.

4.13.13 Means shall be provided to drain collected liquids and to pipe them to the exterior for disposal or redirect them to processes associated with the hydrogen generator.

4.13.14 Where personnel can fully enter the cabinet, ventilation openings shall have a minimum total area of 0.003 m2/m3 of cabinet volume.

4.13.15 External surface temperatures of cabinet components shall meet the limits specified in Section 4.3.2.

4.14 Thermal insulating materials

Insulation systems employed in the hydrogen generator shall be designed to attain:

- chemical compatibility with the metals being insulated, the atmosphere and temperatures to which the systems will be exposed, and the various components of the insulation system itself,
- protection of insulation systems from expected thermal and mechanical abuse (including damage by atmospheric conditions),
- fire safety, by avoiding to increase temperatures around heat producing objects to the extent that these become sufficiently hot to ignite materials in contact with them,
- future accessibility of piping, fittings, etc. for maintenance purposes.

In particular, thermal insulating materials and their internal bonding or adhesive attachment means mounted on components of the hydrogen generator shall:

- be mechanically or adhesively retained in place and shall be protected against displacement or damage from anticipated loads and service operation,
- withstand all air velocities, temperatures and fluids to which they may be subjected in normal operation.

If necessary to avoid hazards to health and safety, the manufacturer shall specify in the maintenance manual the thermal insulation system inspection and safety requirements.

4.15 Utilities

a) The hydrogen generator shall be designed and constructed such that in case of loss of utility supply, i.e. interruption of electrical supply, feed water, cooling water, instrument air, etc., the system shut-downs safely without:

1. the creation of any health or safety hazards;
2. permanent distortion or damage to the system;

b) Where the hydrogen generator requires water to operate, it shall be provided through a connection to an on-site water supply in accordance with the applicable regional and national plumbing codes and standards, or through self-contained water source; or shown to produce water in sufficient quantities during operation.

c) If applicable, means shall be provided to prevent backflow of steam into the water treatment system of the hydrogen generator. A suitable check valve or equivalent device meets the intent of this provision.

4.16 Installation and maintenance

4.16.1 Installation

a) Hydrogen generators shall be installed, adjusted, operated and maintained in accordance to the product's installation manual specified in 6.4.2. Ergonomic principles should be taken into account.

b) Errors, likely to be made when fitting or refitting certain parts which could be a source of risk shall be made impossible by the design of such parts or, failing this, by information given on the parts themselves and/or the housings. The same information shall be given on moving parts and/or their housings where the direction of movement shall be known to avoid a risk. Any further information that may be necessary shall be given in the product's technical documentation.

c) Where a faulty connection can be the source of risk, incorrect fluid connections, including electrical conductors, shall be made impossible by the design or, failing this, by information given on the pipes, cables, etc. and/or connector blocks.

4.16.2 Maintenance

a) Adjustment, lubrication and maintenance points shall be located outside zones in which a person is exposed to risk of injury or damage to health; or maintenance instructions shall be provided in the product's maintenance manual specified in 6.4.5 as necessary to avoid risks to health or safety.

b) It shall be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while the hydrogen generator is at a standstill. When adjustment, maintenance, repair, cleaning and servicing must be conducted while the generator is operating, means shall be provided to do this safely.

c) In the case of automated hydrogen generators the manufacturer shall make provision for a communication device for diagnostic faultfinding equipment.

d) Automated hydrogen generator components that have to be changed frequently shall be capable of being removed and replaced in safety. Access to the components shall enable these tasks to be carried out with the necessary technical means (tools, measuring instruments, etc.) in accordance with the product's technical documentation.

e) Internal parts requiring frequent inspection, and adjustment and maintenance areas, shall be provided with appropriate lighting, where required.

f) Where for protection of health or safety instructions or diagrams are to be adhered to the hydrogen generator, they shall be displayed using a permanent method, resistant to or protected from the environmental conditions of use.

5 Test methods

All the following tests are type or qualification tests. A design examined for compliance with this standard shall be a representative production sample of the hydrogen generator.

Each new design shall be subjected to the qualification tests.

Hydrogen generators shall be subjected to the following routine tests prior to delivery.

a) Every manufactured hydrogen generator:

- Leakage test of the hydrogen generator section(s) carrying flammable fluids, as per 5.5
- Dielectric withstand (hypot) test on the generator's high voltage circuitry, as per 5.11

- Protective bonding circuit continuity test, as per 5.11

b) On a periodic basis to be agreed upon by the manufacturer and the conformity assessment organization:

- CO emissions test when the hydrogen generator is operating under equilibrium conditions, as per 5.13.1.
- Burner operating characteristics as per 5.7

5.1 General requirements

When used for the measurement of temperatures, a thermocouple or equivalent temperature-measuring device shall conform to IEC 62282-3-2.

5.2 Test fuels and pressures

a) A hydrogen generator intended for use with natural gas shall have the tests specified herein conducted with a gas whose composition and supply pressures reflects that of commercially available natural gas. If required by the country of destination, the tests shall also be conducted with limit gases.

b) A hydrogen generator intended for use with liquefied petroleum gases shall have the tests specified herein conducted with a gas whose composition and supply pressures reflects that of commercially available liquefied petroleum gas. If required by the country of destination, the tests shall also be conducted with limit gases.

c) A hydrogen generator for use with other type of fuel shall be tested with a test fuel of composition and supply characteristics agreed upon by the manufacturer and the conformity assessment organization.

d) A hydrogen generator using more than one type of fuel need to be tested with only one test fuel, provided that there are no changes in equipment and ratings for the other fuels that, in opinion of the conformity assessment organization, would affect the results of the tests.

5.3 Basic test arrangements

In conducting the tests the entire hydrogen generator, including any air filters, start-up devices, venting or exhaust systems and all field furnished equipment shall be installed and operated in accordance with the manufacturer's instructions.

Unless otherwise stated, the entire hydrogen generator shall be operated:

a) at the inlet test pressure as defined in 5.2;

b) within 2 percent of the rated input voltage and frequency; and

c) within 5 percent of the rated fuel consumption when operated at rated hydrogen output conditions, as specified by the manufacturer

d) at reference conditions specified as follows:

Reference temperature : t_0 = 293.15 K (20°C)

Reference pressure : p_0 = 101.325 kPa

Testing shall commence when the hydrogen generator components are at equilibrium temperature, unless otherwise specified.

5.4 Pressure Testing

A hydrostatic pressure test shall be performed last or, when judged feasible, on parts not used for other tests specified herein.

Where the manufacturer considers a hydrostatic pressure test impractical, a pneumatic test shall be substituted recognizing the hazard of energy stored in compressed gas.

Any listed or similarly-recognized part(s), when pressure-rated at not less than the design pressure shall be considered as conforming to the applicable provision of this section.

Prior to the conduction of the pressure testing, it shall be established which parts, through (inter) connection, are subjected to the same internal pressure during normal operation of the hydrogen generator. These parts shall comprise an individual test section that shall then be pressurized separately and, when deemed necessary, isolated from the rest of the hydrogen generator by any convenient means.

5.4.1 Hydrostatic Test Method:

Test Fluid: The test fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping system. In that case, another suitable nontoxic liquid may be used. If the liquid is flammable, its flash point shall be at least 50°C and consideration shall be given to the test environment.

Test Pressure: The hydrostatic test pressure at any point on a test section made of metallic components shall be as follows:

a) not less than 1.5 times the design pressure

b) for design temperature above the test temperature, the minimum test pressure shall be calculated by the following equation, except that the value of S_T/S shall not exceed 6.5.

$$P_T = 1.5\ (PS_T)/S$$

Where:

P_T = minimum test gage pressure

P = internal design gage pressure

Metallic test sections:

S_T = stress value at test temperature from Table A-1 of ANSI B31.3 (as per ISO 15649)

S = stress value at design temperature for Table A-1 of ANSI B31.3 (as per ISO 15649)

Non-metallic test sections:

S_T = stress value at test temperature from Table B-1 of ANSI B31.3 (as per ISO 15649)

S = stress value at design temperature for Table B-1 of ANSI B31.3 (as per ISO 15649)

(refer to ANSI B31.3 section 345.4 for details)

c) If the test pressure would produce a nominal pressure stress or longitudinal stress in excess of yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature.

d) A preliminary test using air at more than 170 kPa gage pressure may be made prior to hydrostatic testing to locate major leaks.

e) Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

f) Where the test pressure of the piping exceeds the vessel test pressure and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure provided the manufacturer agrees and the vessel test pressure is not less than 77-percent of the piping test pressure calculated in accordance to the formula above.

Non-metallic test sections: the hydrostatic test pressure at any point in a test section made of non-metallic components shall be not less than 1.5 times the design pressure, but shall not exceed 1.5 times the maximum rated pressure of the lowest rated component in the system. Thermoplastic piping in which the design temperature is above the test temperature, the hydrostatic formula above applies except that S and S_T shall be from Table B-1 of ANSI B31.3.

Procedure: A test section shall be filled with the test liquid and connected to a suitable hydraulic system, including a pressure-measuring device, capable of sustaining the required test pressure. Care should be taken to liberate any air from the test section. The pressure shall then be gradually increased in steps until the test pressure is reached holding the pressure at each step long enough to equalize the piping strains. The final pressure shall be held for 30 minutes. The pressure shall then be reduced to the design pressure before examining for damage.

Results Criteria:

The parts under pressure shall withstand the hydrostatic test pressures without rupture, fracture or other physical damage.

5.4.2 Pneumatic Test Method:

Test Fluid: The test gas used, if not air, shall be nonflammable and nontoxic. For example, clean dry air or any inert gas, such as nitrogen or helium, may be used.

Test Pressure: The test pressure shall be 110-percent of design pressure.

Procedure: A test section shall be filled with the test gas and connected to a suitable pressurizing system, capable of supplying the gaseous medium at the required test pressure. A test section shall be filled with the test gas and connected to a suitable pressurizing system, including a pressure-measuring device, capable of sustaining the required test pressure. The pressure-measuring device shall be located between the pressurizing system and the piping under test. The test section shall be sealed by any convenient means.

The pressure shall then be gradually increased in steps until the test pressure is reached holding the pressure at each step long enough to equalize the piping strains. The final pressure shall be held for 30 minutes. The pressure shall then be reduced to the design pressure before examining for damage.

Results Criteria: The parts under pressure shall withstand the pneumatic test pressures without rupture, fracture or other physical damage.

5.5 Allowable leakage

The procedures of this section shall be performed twice. First prior to the conduction of all tests specified in Sections 5.6 through 5.13. This section shall then be repeated after the product has been conditioned by the performance of the tests specified in Sections 5.6 through 5.15.

All portions of the hydrogen generator that may contain flammable or combustible mixtures must be tested for leakage.

Prior to the conduction of the leakage testing, it shall be established which parts, through (inter) connection, are subjected to the same internal pressure during normal operation of the hydrogen generator. These parts shall comprise an individual test section that shall then be pressurized separately and, when deemed necessary, isolated from the rest of the hydrogen generator by any convenient means.

5.5.1 Leak Test Method for Hazardous Liquid Containing Portions of the System

This test method is used for evaluating hazardous liquid containing portions of the system.

Test Fluid: The test fluid shall be the liquid fuel unless the manufacturer considers that testing with the liquid fuel is impractical. Then the test fluid shall be water unless there is the possibility of damage due to freezing or to adverse effects of water on the piping system. In that case, another suitable non-toxic liquid may be used. If the liquid is flammable, its flash point shall be at least 50°C and consideration shall be given to the test environment.

Test Pressure: The hydrostatic test pressure at any point on a test section made of metallic components shall be as follows:

a. not less than 1.5 times the design pressure

b. for design temperature above the test temperature, the minimum test pressure shall be calculated by the following equation, except that the value of S_T/S shall not exceed 6.5.

$$P_T = 1.5\ (PS_T)/S$$

Where:

P_T = minimum test gage pressure

P = internal design gage pressure

Metallic test sections:

S_T = stress value at test temperature from Table A-1 of ANSI B31.3 (as per ISO 15649)

S = stress value at design temperature for Table A-1 of ANSI B31.3 (as per ISO 15649)

Non-metallic test sections:

S_T = stress value at test temperature from Table B-1 of ANSI B31.3 (as per ISO 15649)

S = stress value at design temperature for Table B-1 of ANSI B31.3 (as per ISO 15649)

(refer to ANSI B31.3 Sections 345.4 and A345.4 for details)

c. If the test pressure would produce a nominal pressure stress or longitudinal stress in excess of yield strength at test temperature, the test pressure may be reduced to the maximum pressure that will not exceed the yield strength at test temperature.

d. A preliminary test using air at more than 170 kPa gage pressure may be made prior to hydrostatic testing to locate major leaks.

e. Where the test pressure of piping attached to a vessel is the same as or less than the test pressure for the vessel, the piping may be tested with the vessel at the piping test pressure.

f. Where the test pressure of the piping exceeds the vessel test pressure and it is not considered practicable to isolate the piping from the vessel, the piping and the vessel may be tested together at the vessel test pressure provided the manufacturer agrees and the vessel test pressure is not less than 77-percent of the piping test pressure calculated in accordance to the formula above.

Non-metallic test sections: the hydrostatic test pressure at any point in a test section made of non-metallic components shall be not less than 1.5 times the design pressure, but shall not exceed 1.5 times the maximum rated pressure of the lowest rated component in the system. Thermoplastic piping in which the design temperature is above the test temperature, the hydrostatic formula above applies except that S and S_T shall be from Table B-1 of ANSI B31.3.

Procedure: A test section shall be filled with the test liquid and connected to a suitable hydraulic system, including a pressure-measuring device, capable of sustaining the required leak test pressure. Care should be taken to liberate any air from the test section. The pressure shall then be gradually increased in steps until the leak test pressure is reached holding the pressure at each step long enough to equalize the piping strains. The test pressure shall be held for at least ten minutes and until all joints and connections are examined for leakages.

Results Criteria: The test section shall show no signs of leakage during the test.

5.5.2 Leak Test Method for Hazardous Gas Containing Portions of the System

This leak test method is used for portions of the system containing hazardous gases.

Test Fluid: Portions containing gas or vapours must be tested with non-flammable and non-toxic gases or vapours (e.g. clean dry air or any inert gas) that correlate with the expected constituents during operation and shutdown.

Test Pressure: The gaseous leak test pressure shall be 110-percent of the design pressure.

Procedure: A test section shall be filled with the test gas and connected to a suitable pressurizing system, including a pressure-measuring device, capable of sustaining the required leak test pressure and a flow measuring device or pressure decay device to determine leakage. The leakage-measuring device shall be located at the inlet to the portion under test after the pressure-measuring device. The test section shall be sealed by any convenient means.

The pressure shall then be gradually increased in steps until the leak test pressure is reached holding the pressure at each step long enough to equalize the piping strains. The test pressure shall be held for at least ten minutes, at which time any leakage, as indicated by the flow-measuring device or other leak detection means such as pressure decay device, shall be noted.

Results Criteria: The total hydrogen generator leak rate shall be such that for the provided ventilation each of the flammable gases can be diluted to levels below 25-percent LFL.

5.5.3 Leak Test Method for Direct Vent Systems

Joints in direct vent systems shall be tight. A venting system shall be gastight and watertight. This provision shall be deemed met if leakage from the system is not in excess of the limits specified in the following Method of Test.

Method of Test

This test shall be conducted using the maximum air intake and vent pipe length and number of joints, including fittings, as specified by the manufacturer. For purposes of this test, the manufacturer shall supply (1) the venting system which incorporates the maximum specified number of fittings, and (2) a sealed test fitting incorporating the vent collar to which the venting system is to be attached. This test fitting shall also have an inlet tap(s) to which a pressure source and a pressure-measuring device can be attached.

The entire vent-air intake system, including the piping and terminal cap, shall be installed (and sealed, if applicable) in accordance with the manufacturer's instructions.

a) Appliances having a separate air intake section and a separate exhaust-vent section

The vent and air intake terminals shall be removed, and the entrance of the air intake section sealed at the point it enters the fuel cell stack. The entire system, including the process air and exhaust gas connections between the appliance and the vent and air intake terminals, shall be installed and sealed in accordance with the manufacturer's instructions.

Both the exhaust outlet and the air inlet shall then be sealed at the point of connection to the vent and air intake terminals. The sealing means shall include fittings for supplying air to both the air intake and exhaust sections of the system and provisions for measuring the internal pressure in each section of the system.

The internal pressure in the system shall be determined by connecting the means for determining internal pressure to a water-filled manometer that may be read directly to 2.5 Pa.

A suitable supply of clean air shall be permitted to flow through a metering device and into the section of the direct vent system being pressurized through the air supply fitting. The air supply fitting to the section of the system not being pressurized shall be open.

The internal pressure in the section of the system being pressurized shall be adjusted to (1) 25 Pa above the normal operating system pressure for forced draft systems operating at positive combustion chamber pressures and (2) 25 Pa for all other systems. The leakage rate shall be noted for both the air intake and exhaust sections of the direct vent system.

This provision shall be deemed met if leakage from the exhaust section of the system does not exceed 2 - volume percent of the effluents and leakage from the air intake section of the system does not exceed 8 - volume percent of the effluents.

b) Appliance with all or part of the vent portion of the exhaust section enclosed within the air intake section

On these appliances, the exhaust-vent section of the system shall be considered that portion of the exhaust-vent section not contained within air intake section.

The vent-air intake terminal shall be removed, and the entrance of the air intake section sealed at the point it enters the fuel cell stack. The entire system including the process air and exhaust gas connections between the appliance and the vent-air intake terminal, shall be installed and sealed in accordance with the manufacturer's instructions. Any vent extension located within the air intake section need not be installed.

The direct vent system shall then be sealed at the point of connection to the vent-air intake terminal. The sealing means shall include fittings for supplying air simultaneously to the air intake and exhaust-vent sections of the system and provisions for measuring the internal pressure.

Using the test apparatus and the method of test specified in (a), the total system shall be pressurized and the leakage rate noted.

The exhaust section of the system shall then be sealed, with the appropriate fittings noted above, at the first joint of the vent portion of the exhaust section contained within the air intake section downstream of the fuel cell stack. Using the test apparatus and the method of test specified in (a), the exhaust section shall be pressurized and the leakage rate noted.

This provision shall be deemed met if leakage from the exhaust section of the system does not exceed 2 - volume percent of the effluents, and leakage from the total system does not exceed 8 - volume percent of the effluents plus the leakage, determined for the exhaust-vent section.

5.6 Protection parameters

Compliance with this section shall be established for each critical failure mode resulting from the safety and reliability analysis described in 4.1.2 using a simulated test procedure or supportive evidence from the manufacturer, as agreed upon with the conformity assessment organization, either of which verifies that the required action will occur.

Means shall be provided for automatic shutdown of the appropriate system(s) of the hydrogen generator for any of the critical failure modes resulting from the safety and reliability analysis described in 4.1.2.

Means shall be provided for automatic shutdown of the appropriate system(s) of the hydrogen generator for any of the critical failure modes defined in Section 4.6.

Means shall also be provided for any necessary permissives required as per Section 4.9.2.3 to avoid the creation of critical failure modes or unsafe conditions, where sequential phases of system operation require certain conditions to be satisfied prior to initiating those applicable sequential phases of operation.

5.7 Burner operating characteristics

The procedures of this section are applicable to hydrogen generators equipped with any fuel-fired boiler or heating device, e.g. the start burner of the reformer section, and shall be performed with the burner both hot and cold for the following conditions:

a) at the test pressures and using test gases as defined in 5.2,

b) at the maximum and minimum fuel supply pressures specified by the manufacturer, if different from those pressures defined in Section 5.7a,

c) when operating at 85-percent and 110-percent of the rated input voltage. When provided with voltage variation protection within this range, the system shall be tested at the specified limits. In addition, the voltage variation protection shall be verified as per Section 5.6.

b)

5.7.1 General testing

The automatic ignition system shall effect ignition of burner fuel immediately after the fuel reaches the burner port(s). A continuous pilot, when provided, shall not extinguish when the burner fuel gas is turned “on” or “off”. This provision does not apply to an intermittent or interrupted type pilot when the burner fuel is turned “off”.

During the test it shall be verified that:

a) the burner fuel ignites effectively without delayed ignition, flashback, undue noise or equipment damage,

b) the burner flames extinguish without flashback and undue noise,

c) the burner flames do not flash outside the combustion chamber,

d) the burner does not deposit carbon, and

e) there is no gas escaping or backpressure at the burner’s primary air openings.

5.7.2 Limit testing

The test is carried out without altering the adjustment of the burner and ignition burner. The pressure at the inlet is reduced to 70 % of the normal pressure. Under these supply conditions, it is checked that the burner is safely operating, and that the CO emissions remain below the level required in Section of 4.3.7. This test is repeated at the minimum heat input permitted by the controls, if ignition is possible under these conditions.

5.8 Automatic control of burners and catalytic oxidation reactors

The procedures of this section are associated with the start of all components intended to conduct a controlled oxidation reaction, e.g. combustion (start burner of a reformer section), catalytic partial oxidation and catalytic combustion.

5.8.1 Automatic ignition control burners

The automatic ignition control of hydrogen generators burners shall be tested as per the following tests:

5.8.1.1 Effective Ignition

The igniter shall light the main burner fuel immediately after fuel reaches the main burner ports. With the hydrogen generator maintained at rated voltage, the igniter shall be activated and ignition observed. Flames shall not flash outside of the hydrogen generator, nor shall there be any damage to the hydrogen generator.

A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur immediately after fuel reaches the main burner ports.

5.8.1.2. Ignition - voltage variation

a. Undervoltage

The voltage to the hydrogen generator shall be adjusted to 85-percent of the rating plate voltage. Under this condition, the igniter shall light the main burner fuel within the main flame establishing period. The CO emissions shall be measured to verify compliance with the requirement of section 4.3.7. Flames shall not flash outside the hydrogen generator, nor shall there be any damage to the hydrogen generator.

A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur within the designated time.

b. Overvoltage

The voltage to the hydrogen generator shall be adjusted to 110-percent of the rating plate voltage. Under this condition, the igniter shall light the main burner fuel within the main flame establishing period. The CO emissions shall be measured to verify compliance with the requirement of section 4.3.7 Flames shall not flash outside the hydrogen generator, nor shall there be any damage to the hydrogen generator.

A sufficient number of ignition attempts shall be made, and in each instance ignition shall occur within the designated time.

5.8.1.3 Flame establishing period

The flame establishing period shall be checked when the hydrogen generator is being operated as specified in Section 5.3. The time from energizing the main fuel flow to the time of proof of the ignition device or burner flame, as applicable, shall not exceed the appropriate flame-establishing period as specified in Section 4.6.4.

5.8.1.4. Flame failure lock-out time

The hydrogen generator shall operate at its rated fuel consumption rate until thermal equilibrium is achieved. The flame failure lock-out time is measured between the moment when the pilot (if equipped) and main burner are intentionally extinguished by shutting off the fuel and the moment when, after admission of the fuel is restored, it ceases by the action of the safety device. The safety device shall de-energize all fuel safety shutoff valves within the flame failure lock-out time specified in section 4.6.4.

With the burner alight, flame failure is simulated by disconnection of the flame detector, and the time is measured that elapses between this moment and that when the flame supervision device effectively shuts off the fuel supply.

For the purposes of this test, the control manufacturer's specified maximum flame failure lock-out time shall be used.

5.8.1.5. Recycling/Spark restoration

With a recycling ignition system, the recycle time shall be checked with the hydrogen generator being adjusted to its rated fuel consumption rate. The recycle time is the period of time between shut off of the fuel supply following loss of flame and reactivation of the igniter. When spark restoration occurs, it shall be verified that after flame failure the igniter effectively re-lit the fuel within the flame establishing period. Flames shall not flash outside the hydrogen generator, nor shall there be any damage to the hydrogen generator.

With the burner alight, flame failure is simulated by disconnection of the flame detector. Observe the time that elapses between flame outage to when the flame detector acts to shutdown fuel flow. Also, observe the time that elapses between the moment when the fuel flow stops to when the igniter re-energizes.

For the purposes of this test, the control manufacturer's specified maximum flame failure lock-out time and minimum recycle time shall be used.

5.8.1.6. Pilot Flame Reduction

A pilot, when provided, shall effect safe ignition of fuel at the burner when the pilot fuel supply is reduced to an amount just sufficient to keep the safety shutoff valve open or just above the point of flame extinction, whichever represents the higher pilot fuel rate. Flames shall not flash outside the hydrogen generator, nor shall there be any damage to the hydrogen generator.

For purposes of this test, the control manufacturer's specified maximum flame failure lock-out time shall be used.

This test shall be initiated from both a cold start and immediately after the hydrogen generator has been shutoff after equilibrium condition.

5.8.1.7. Delayed Ignition

For an hydrogen generator that is arranged for ignition of the main burner directly by an electric igniter, delay of ignition of the fuel shall not result in flashback of flame to the outside of the hydrogen generator or any damage to the hydrogen generator and the connected vent system. For purposes of this test, the control manufacturer's specified maximum trial for ignition period for the automatic fuel ignition system shall be used. For systems that deactivate the igniter prior to the end of the trial for ignition period, the test shall be conducted using the control manufacturer's specified maximum ignition activation period timing.

With the hydrogen generator at room temperature, the hydrogen generator shall be placed into operation at normal heat input rate with the ignition means temporarily circumvented for varying intervals of time up to the control manufacturer's maximum specified trial for ignition period or maximum specified ignition activation period, whichever is shorter. For multi-try systems, attempts to ignite shall be made for varying intervals of time for each trial for ignition period and any time the ignition means is activated throughout the total operating sequence up to lockout.

The ignition of the main burner shall be observed for each of the trials. There shall be no flame flashout or damage to the hydrogen generator.

Delayed ignition testing is also used to confirm the flame establishing period provided by the manufacturer.

5.8.1.8 Ignition System Components Temperature Test

Thermocouples or equivalent temperature measuring devices shall be suitably attached to applicable points of each ignition system component. The hydrogen generator shall be operated at rated fuel consumption rate until equilibrium condition is obtained. Temperatures of the components shall then be obtained. The temperatures obtained shall not exceed those for which the components are listed.

5.8.1.10 Pre-purge

This test is applicable to systems that require purge as per Section 4.6.4q.

According to the option chosen by the manufacturer, the pre-purge volume or the pre-purge time are determined as follows:

a) Pre-purge volume

1) The rate is measured at the outlet of the combustion products evacuation duct, at ambient temperature.

2) The hydrogen generator is at ambient temperature and not operating. The fan is supplied with electricity under actual pre-purge conditions.

3) The rate, measured with a limit of error of +/- 5-percent, is corrected to reference conditions.

4) The manufacturer states the volume of the combustion circuit.

b) Pre-purge time

1) The hydrogen generator is at ambient temperature and not operating.

2) The time between the fan starting and the ignition device being energised is determined.

It is checked that the requirements of 4.6.5 are satisfied.

5.8.2 Automated control of catalytic oxidation reactors

a) The time of initiation of fuel flow to proof of the reaction initiation shall not exceed the reaction initiation time specified in 4.6.5.

Method of test

The hydrogen generator shall be operated as specified by the manufacturer until conditions for reaction initiation are attained. Then, the fuel supply for air-rich operation, or for fuel-rich operation, the supply of air, shall be opened. The system response time shall begin at that point of time and shall end when the reactor monitoring devices signal as specified by the manufacturer that the reaction has been successfully initiated. The reaction initiation time shall not exceed the value specified in 4.6.5.

b) In the event of reaction extinction or reaction rate decrease or increase to unsafe levels, the primary safety control shall de-energize the fuel safety shutoff valve for air-rich operation, or for fuel-rich operation, the air safety shutoff valve followed suit by the de-energizing of the fuel safety shutoff valve, within the reaction failure lock-out time specified in 4.6.5.

Method of test

The hydrogen generator shall be operated as specified in 5.3 until equilibrium conditions are attained.

Then, the fuel supply for air-rich operation, or for fuel-rich operation, the supply of air, shall be shut off.

With the catalytic reactor alight, reaction failure is simulated by disconnection of the device monitoring the reaction temperature. The time measured between this moment and the time when the system control shuts off the fuel supply for air rich operation, or the supply of all reactants for fuel-rich operation, shall not exceed the reaction failure lock-out time specified in 4.6.5.

5.9 Mechanical Testing of Vent Systems

5.9.1 Pull and Torque Tests

Method of test

The venting system shall be installed on the hydrogen generator in accordance with the manufacturer's instructions. The venting system components are to be assembled such that the vent pipe extends beyond the appliance casing. If cemented joints are included in the assembly of the hydrogen generator vent system, the cement shall be allowed to dry as specified by the manufacturer's instructions.

A 223N force shall be applied along the longitudinal centerline of the vent pipe in a direction tending to pull the vent from the hydrogen generator. A similar force is then applied in the opposite direction. In each case the force is applied for five minutes.

A torque of 34 N-m is applied to the centerline of the assembly and applied for 1 minute from one rotation direction. The torque is then applied in the opposite direction for 1 minute. Rotation of the vent pipe with respect to the exhaust collar is acceptable, if the joint then passes the following vent leakage test.

After test, the vent connections and other internal parts shall be examined for signs of leakage, breakage, or disassembly. This provision shall be deemed met if the hydrogen generator meets the blocked outlet combustion test and vent leakage tests specified in Sections 5.13 and 5.5. Direct vent hydrogen generators shall meet the blocked outlet combustion requirement and the allowable vent leakage requirements.

5.9.2 Load Test on Vent Termination

Method of test

The minimum vent system shall be assembled in accordance with the manufacturer's installation instructions. A vertical suspension load of 68 kg shall then be evenly distributed without impact over the vent terminal. The load shall be removed and shall not have caused substantial distortion of any part of the vent terminal or alteration of its position relative to the hydrogen generator so the appliance would not operate satisfactorily.

The hydrogen generator shall then be operated at normal input rate until equilibrium conditions are attained. A sample of the effluents shall then be taken and analyzed and the concentration of carbon monoxide, based on an air-free sample, shall not exceed the requirements of Section 4.3.7.

5.9.3 Impact Test on Vent Termination

Method of test

A bag, filled with sand, weighing 12 kg is suspended from a cable or rope that is 2.20 m in length. The impact is produced by a pendulum action. The bag shall have an at-rest position not more than 25 mm from the edge of the bag to the edge of the vent terminal. The point of impact shall be opposite the center of gravity of the bag. The distance of swing shall be measured (45 degrees) as the angle between the pendulum arm with the bag at its at-rest position and pendulum arm at its elevated position. The length of the pendulum measured from the point of rotation to the center of gravity of the bag shall be 2.20 m.

One impact shall be made at each of the following points:

a. The center of the vertical front surface of the vent terminal.

b. The leading edge on the left side of the vent terminal, pendulum rotated left at an angle 45 degrees from the point described in "a."

c. The leading edge on the right side of the vent terminal, pendulum rotated right at an angle 45 degrees from the point described in "a."

Following each impact, the hydrogen generator shall be operated at normal input rate until equilibrium conditions are attained. A sample of the effluents shall then be taken and analyzed and in each case the concentration of carbon monoxide on an air-free sample shall not exceed the requirements as shown in Section 4.3.7.

At the manufacturer's discretion, the vent terminal may be replaced following each impact and combustion test.

5.10 Surface and component temperatures

When the hydrogen generator has attained equilibrium operating conditions, temperatures shall be measured to determine that the requirements of Sections 4.3.2, 4.3.13, and, if applicable, 4.6.2 and 4.6.3 are met.

5.10.1 Wall, Floor and Ceiling Temperatures

The hydrogen generator is placed on the test panels made of wood.

The manufacturer shall specify the distance between the hydrogen generator and the back and sidewalls (and closet door, if applicable) of the test panels.

The hydrogen generator is placed on the test panels having the following specifications:

Dull black-painted plywood approximately 20mm thick is used for the test panels.

Temperature rises are determined by means of fine-wire thermocouples. Thermocouples having wires with a diameter not exceeding 0.3 mm are considered to be fine-wire thermocouples.

Thermocouples used for determining the temperature rise of the surface of walls, ceiling and floor of the test corner are attached to the back of small blackened disks of copper or brass, 15 mm in diameter and 1 mm thick. The front of the disk is flush with the surface of the boards.

As far as possible, the hydrogen generator is positioned so that the thermocouples detect the highest temperatures.

The hydrogen generator shall be operated at maximum power output. After equilibrium temperatures have been obtained, the temperature of the test panels shall be measured and checked whether the requirements of Section 4.3.2.a are met.

5.10.2 Temperature of Polymeric Components

Thermocouples shall be placed on the polymeric components to measure their temperature. During the conduct of the wall, floor and ceiling temperature test, the highest operating temperature of the polymeric components shall be determined for use below.

The functional integrity of a polymeric component shall be determined after it has been exposed to a temperature of not less than 70 ^{o}C, or a temperature of 10 ^{o}C above the highest operating temperature, whichever is greater, for 7 hours in a full draft circulating-air oven. There shall be no shrinkage, warpage, or other distortion of the component that would cause the hydrogen generator not to comply with any other provisions of this standard.

5.10.3 Outlet piping temperature

Outlet piping temperatures shall be determined using the following method.

When the hydrogen generator has attained equilibrium operating conditions, the temperature of all outlet piping shall be measured. The temperature obtained shall not exceed the temperature for which the outlet piping material has been determined to be acceptable.

5.11 Electrical tests

The hydrogen generator shall be tested as per IEC 60204-1 or IEC 60335-1 as applicable.

5.12 Wind tests

5.12.1 Wind Source Calibration Procedure for Winds Directed Perpendicular to the Wall

The wind source calibration configuration shall consist of the center of the wind source being directed perpendicular to the center of a test wall equipped with 4 ports located around a vent terminal which is installed in the center of the test wall, in accordance with the manufacturer's installation instructions (see Appendix 4, Figure: Test Wall with Static Pressure Ports and Vent Terminal Locations). The ports shall be manifolded to obtain a single average static pressure reading. With the wind source directed against the wall, the average static pressure reading as measured by a manometer referenced at the hydrogen generator combustion air opening shall form the basis for calibrating the wind source using the following relationships:

Nominal km/h	Average Static Pressure (Pa)
16	10
50	100

Additionally, the wind source calibrated at 50 km/h shall not generate a velocity pressure exceeding 12 Pa [16km/h] at a distance of 305 mm perpendicular to the test wall and in line with the ports.

5.12.2 Verification of operation of outdoor hydrogen generators under wind conditions

The procedures of this section apply only to hydrogen generators intended for outdoor installation or components of hydrogen generators intended for outdoor installation.

Cabinets of hydrogen generators intended for outdoor installation or enclosures of components of hydrogen generators intended for outdoor installation shall be subject to and pass a wind test as per the following method:

Method of test

The hydrogen generator shall start and operate normally, without damage or malfunctioning of any part and without creating a hazardous or unsafe condition, when exposed to winds having nominal velocities up to and including 50 km/h.

A wind, produced by a fan/blower of sufficient capacity to develop a draft having a velocity up to and including 50 km/h, shall be directed against an outer surface of the hydrogen generator at the point(s) deemed most critical by the testing agency. The fan/blower shall be located so a uniform wind, covering the entire projected area of the outer surface, is directed horizontally toward the hydrogen generator at the specified velocity measured in a vertical plane 50 cm from the windward surface of the hydrogen generator.

With the hydrogen generator subjected to a wind having a nominal velocity of 16 km/h, the pilot, when provided, shall be capable of being ignited.

With the hydrogen generator subjected to a wind having a nominal velocity of 50 km/h, the burner gas shall ignite from the ignition device without excessive delay and the burner and pilot flames shall not extinguish. The pilot, when provided, shall be operated alone, as well as simultaneously with the burner.

At the discretion of the conformity assessment organization, additional tests may be conducted with winds of specified and unspecified velocities directed from other direction(s).

5.12.3 Verification of operation of indoor hydrogen generators vented horizontally through an outside wall

Method of Test

These tests shall be conducted at normal inlet test pressure.

a. The hydrogen generator shall meet the requirement of Section 4.5.2.1 (l) when testing with a wind direction other than perpendicular to the wall, except that the wind produced by the wind source shall have a nominal velocity of 50 km/h (117 Pa free-stream velocity pressure) measured with the wind parallel to the wall with a Pitot tube at three locations positioned on a plane perpendicular to the wall and also bisecting the vent system. The three locations shall be at distances of 305mm horizontally and vertically from the extremities of the vent system]. See Appendix 5.

After the calibration of the wind source parallel to the wall the wind source or test wall shall be rotated to direct the wind from other angles at the discretion of the test agency.

b. For wind directed perpendicularly to the wall, either of the following test methods shall apply.

1. The following test method shall be applied at the maximum vent length specified.

Remove only the vent terminal from the horizontal vent, when a vent terminal is used. Equip the vent pipe with a piezo ring 305 mm from the outlet of the horizontal vent [See Appendix 6, Figure: Piezo Ring and Details of Typical Construction]. Connect the piezo ring to a differential pressure gage that can be read directly to within 1.24 Pa pressure. The manometer reference pressure connection shall be extended to a point adjacent to the fuel cell combustion air supply opening.

Start hydrogen generator operation. Restrict the end of the vent until the pressure at the piezo ring reaches 100 Pa. Stop hydrogen generator operations. Turn on gas supply to the hydrogen generator. With the restriction still in place, start the hydrogen generator operation from a cold start. While under the above condition, the hydrogen generator shall not shut down. After steady-state conditions are attained readjust the restriction to maintain 100 Pa. While operating under the above condition, the hydrogen generator shall not shut down during a 10-minute period. While maintaining the vent pressure of 100 Pa the hydrogen generator shall be turned on and off by the automatic controls, and the hydrogen generator shall start up without excessive delay.

2. The following test method shall be applied at the maximum vent length specified.

The wind produced by the wind source shall have a nominal velocity of 50 km/h calibrated as specified in Section 5.12.1.

The hydrogen generator shall not shutdown during a 10-minute period when exposed to a 50 km/h wind.

The hydrogen generator shall also continue to operate when cycled on and off by the automatic controls

5.12.4 CO Emissions under Wind - Indoor Units:

For hydrogen generators installed indoors, the CO emissions shall be checked when a wind ranging from zero to 50 km/h is exerted against the vent-air intake terminal(s). The wind is applied from any horizontal direction with respect to the vent-air terminals. The vent-air intake system is exposed to a 50km/h wind velocity [Free-steam velocity pressure of 117 Pa measured with a Pitot tube at three locations on a plane perpendicular to the wall and also bisecting the vent-air intake system. The three locations shall be at distances of 305 mm horizontally and vertically from the extremities of vent-air intake system]. The hydrogen generator shall operate at nominal input rate until a constant exhaust gas temperature is achieved. During the application of this range of wind velocities, the CO emissions are measured to verify compliance with the requirement of Section 4.3.7.

After the calibration of the wind source parallel to the wall the wind source or test wall shall be rotated to direct the wind from other angles at the discretion of the conformity assessment organization.

5.12.5 CO Emissions under Wind - Outdoor Units

For hydrogen generator installed outdoors, the CO emissions shall be checked when the appliance is exposed to a wind ranging from zero to 50 km/h. A wind, produced by a blower of sufficient capacity to develop a draft having a velocity up to and including 50 km/h , shall be directed against an outer surface of the hydrogen generator at the points deemed most critical by the conformity assessment organization. The blower shall be located so a uniform wind, covering the entire projected area of the outer surface, is directed horizontally toward the hydrogen generator at the specified velocity measured in a vertical plane 0.5m from the windward surface of the hydrogen generator. The hydrogen generator shall operate at nominal input rate until a constant exhaust gas temperature is achieved. During the application of this range of velocities, the CO emissions are measured.

5.13 CO Emissions

5.13.1 Operation under equilibrium conditions

When the hydrogen generator has attained equilibrium operating conditions, CO emissions shall be measured to verify compliance with the requirement of Section 4.3.7.

5.13.2 Blocked Outlet

The CO emissions shall be checked with the hydrogen generator's exhaust outlet blocked to any degree up to and including complete closure. The hydrogen generator shall be operated at nominal heat input rate for at least 15 minutes. When the hydrogen generator incorporates a control to automatically shut off the main fuel supply under blocked outlet conditions, the area of the exhaust outlet shall be gradually decreased to the lowest point at which the control will remain in its open position. The CO emissions shall then be measured to verify compliance with the requirement of Section 4.3.7.

5.13.3 Blocked Air Supply

This test is performed on hydrogen generators that rely on outside air routed through an air intake conduit. The hydrogen generator shall be operated at nominal heat input rate for at least 15 minutes. The following tests shall be conducted:

a) The air intake duct is progressively blocked. The CO emissions shall then be measured to verify compliance with the requirement of Section 4.3.7.

b) With the hydrogen generator at ambient temperature, the air supply duct is reopened gradually. The blockage at which the burner ignites is determined. At this blockage and once thermal equilibrium has been achieved, the CO emissions are measured to verify compliance with the requirement of Section 4.3.7.

5.13.4 Voltage variation

This test is performed on hydrogen generators that rely on outside air routed through an air intake conduit. The hydrogen generator shall be operated at nominal heat input rate for at least 15 minutes. The following tests shall be conducted:

a) The voltage at the fan terminals is progressively reduced. It is checked that the gas supply is shut off before the CO concentration of the combustion products exceeds the requirement of Section 4.3.7.

b) With the hydrogen generator at ambient temperature, the voltage at the fan terminals is progressively increased from zero. The voltage at which the burner ignites is determined. At this voltage, the CO emissions are measured to verify compliance with the requirement of Section 4.3.7.

5.14 Limit Testing Due to Loss of Utility Supply

The hydrogen generator shall be installed and operated as specified in the applicable provisions of 5.3. A test shall be executed for each utility system, i.e. electrical, feed water, cooling water, instrument air, etc. where the utility supply is gradually interrupted.

The system should safely shut-down without:

1. the creation of any health or safety hazards;
2. permanent distortion or damage to the system;

If the hydrogen generator requires a purge gas for protection during shutdown and/or storage, the simultaneous failure of the inert gas and a second utility need not to be tested. However, the test shall verify that loss of purge gas supply results in an alarm such that the duration of the loss of inert supply may be minimized.

5.15 Verification of Operation

The purpose of this test is to verify that the hydrogen output, under the test conditions of 5.3 while using the nominal fuel input, is not less than the nominal hydrogen output. Also, the hydrogen purity shall not be less than the nominal hydrogen purity.

The functions of the hydrogen generator shall be tested, particularly those related to safety and safeguarding. All modes and transition conditions specified by the manufacturer shall be tested. The system should safely operate without:

1. the creation of any health or safety hazards;
2. permanent distortion or damage to the system;

a) The product gas stream flow rate and the fuel supply shall be measured at 100-percent capacity when conditions of equilibrium have been achieved. The fuel supply gas stream shall be measured using the same method for gas streams or as agreed between the manufacturer and the conformity assessment organization for liquid fuels.

The online sampling and analysis procedure shall be agreed between the manufacturer and the conformity assessment organization. During the operational cycle, a sufficient number of samples shall be secured to allow a determination of compliance with this section.

Hydrogen generators that have continuously variable output capacity shall be tested at 25-percent, 50-percent, 75-percent and 100-percent capacity levels.

Hydrogen generators that have different output settings shall be tested at each different output setting.

Each capacity level (or output setting) shall have the measurements made and plotted for one hour.

The output pressure from the hydrogen generator shall be measured using a calibrated pressure gauge at the gas outputs.

Airborne noise emissions shall be determined as per IEC 60704-3.

Based on the measurements made, the following characteristics shall be determined:

- Hydrogen production rate within 1-percent

- Fuel input rate within 1-percent
- Hydrogen content in the output stream on a dry basis,
- Pressure, temperature and humidity of the hydrogen output stream,
- Electrical consumption at rated output
- Airborne noise emissions

Subsequent to tests 5.14 and 5.15, a 720-hour continuous operation test shall be completed as agreed between the manufacturer and the conformity assessment organization.

6. Marking, labelling and packaging

6.1 General requirements

The hydrogen generator shall be marked in compliance with the applicable sections of ISO 4898:

6.2 Hydrogen generator marking

Each hydrogen generator shall bear a data plate or combination of adjacent labels located so as to be easily read when the hydrogen generator is in a normally installed position.

The marking shall clearly state any restrictions on use, in particular the restriction whereby the hydrogen generator shall be installed only in areas where there is sufficient ventilation.

The data plate/label(s) shall include the following information:

a) the manufacturer's name (with trademark), and location;

b) the catalogue number and the model number or type;

c) the serial number;

d) the electrical input range in volts;

e) the current rating in amperes;

f) the frequency in hertz and phases;

g) the rated power input in watts;

h) fuel type and quality to be used by the hydrogen generator

i) the permissible range of fuel supply pressures

j) outdoor or indoor use;

k) the capacity of generation of hydrogen in kilograms per hour;

l) the hydrogen content in the output stream on a dry basis,

m) the hydrogen output pressure in kilopascals;

n) the conformity assessment mark that refers to this International Standard (if applicable)

If the hydrogen generator is rated to operate in hazardous areas as per IEC 60079-10, it shall be marked accordingly.

6.3 Marking of components

All types of valves, transmitters, motors, pumps, and fans shall be identified to match the hydrogen generator drawings.

Piping and tubing shall be marked to identify contents and flow direction.

Warning signs shall be appropriately placed to identify electrical hazards, contents from drain valves, hot components and mechanical hazards. Preference should be given to the use of standard symbols given in ISO 3864.

Control devices, visual indicators, and displays (particularly those related to safety) used in the man-machine interface shall be clearly marked with regard to their functions either on or adjacent to the item. Preference should be given to the use of standard symbols given in IEC 60417 and ISO 7000.

6.4 Technical Documentation

6.4.1 General

The manufacturer shall provide with each hydrogen generator the information necessary for safe installation, operation, and servicing of the hydrogen generator and shall in particular draw attention to any restrictions on use. The information shall be provided in form of technical documents such as drawings, diagrams, charts, tables and instructions and these shall be on suitable data medium and language.

Part of the technical information might be provided only to qualified personnel, in which case the manufacturer shall specify criteria for qualification of personnel.

The information provided with the hydrogen generator shall include:

- a clear, comprehensive description of the equipment, installation and mounting, and the connection to electrical supply(ies);
- electrical supply(ies) requirements;
- physical environment and operating conditions (fuel and water supply characteristics, etc.) as per 4.2
- electric circuit diagrams
- information (where appropriate) on:
    a) handling, transportation and storage;
    b) software programming;
    c) sequence of operations;
    d) frequency of inspection;
    e) frequency and method of functional testing;
    f) guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits; and
    g) parts list and recommended spare parts list.

- A description (including interconnection diagrams) of the safeguards, interlocking functions, and interlocking of guards for potentially hazardous situations, particularly for hydrogen generators operating in a co-ordinate manner with other equipment items (e.g. a fuel cell power system or a hydrogen compression, storage and delivery system).

- A description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (e.g. for manual programming, program verification)

6.4.2 Installation manual

The installation manual shall provide the installer all the information necessary for the preliminary work of setting-up the generator.

In particular, an interconnection diagram or table shall be provided. That diagram or table shall give full information about all external connections (e.g. electrical supply, fuel supply, water supply, control signals, exhaust venting, ventilation connections, product delivery interconnection, etc.).

These installation instructions shall provide, as applicable, guidelines on: location and design of the hydrogen generator foundation; ventilation requirements; design, construction and installation of the pressure relief venting pipe, flue gas venting system and product delivery piping; protection from weather hazards; recommended height in relation to the base flood elevation; security enclosure; acceptable distances from combustible materials or ignition sources, vegetation, sidewalks, public ways, roads, and railroad tracks; and protection from vehicular impact, as applicable; clearances around air supply, ventilation and exhaust openings in meters; clearances for maintenance, servicing and proper operation in meters.

6.4.3 User's information manual

For hydrogen generators to be installed as part of systems for residential, commercial and light industrial use (e.g. residential fuel cell power systems), the system supplier shall provide to the hydrogen generator owner a user's information manual, together with any appropriate additional information to facilitate maintenance (e.g. addresses of the importer, repairer, etc.), as per the following specifications:

The user's information manuals shall be in the user's national language.

The user's information manuals shall be typed or typeset and formatted to provide easy-to-follow procedures. Illustrations should be used to identify hydrogen generator components, dimensions and clearances, assembled components, and connection points as needed to make the instructions clear. Illustrations should also be used to identify the location of serviceable components and illustrate correct methods for performing service procedures.

When text is shown in quotation marks, it shall appear in the user's information manual exactly as shown.

The user's information manual shall be affixed to the hydrogen generator in a pocket or attached by a clip which is part of the hydrogen generator or shall be supplied in an envelope(s) marked with instructions (1) to the installer to affix them on or adjacent to the hydrogen generator, and/or (2) to the user to retain them for future reference. Each user's information manual should be divided into appropriate chapters or sections, and should include a table of contents and clearly marked page numbers.

The user's information manual shall contain the following safety information, as applicable:

a. Front Cover:

The front cover shall present the user(s) with only the most important safety instructions. The front cover or, in the absence of a cover, the first page of the manual shall bear the following safety precautions boxed as shown:

FOR ODORIZED GAS

FUELED SYSTEMS:

WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

– **Do not store or use gasoline or other flammable vapours and liquids in the vicinity of this or any other appliance.**

– **WHAT TO DO IF YOU SMELL GAS**

- **Do not try to light any appliance.**
- **Do not touch any electrical switch; do not use any phone in the area.**
- **Leave the area immediately.**
- **Immediately call your gas supplier. Follow the gas supplier's instructions.**
- **If you cannot reach your gas supplier, call the fire department.**

– **Installation and service must be performed by a qualified installer, service agency or the gas supplier.**

FOR ODORANT-FREE GAS

FUELED SYSTEMS:

WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

– **Do not store or use gasoline or other flammable vapours and liquids in the vicinity of this or any other appliance.**

– **Installation and service must be performed by a qualified installer, service agency or the gas supplier.**

FOR LIQUID FUELED SYSTEMS:

WARNING:

FIRE OR EXPLOSION HAZARD

Failure to follow safety warnings exactly could result in serious injury, death or property damage.

– **Do not store or use gasoline or other flammable vapours and liquids in the vicinity of this or any other appliance.**

– **WHAT TO DO IF YOU SEE LIQUID LEAKAGE**

- **Do not try to light any appliance.**
- **Do not touch any electrical switch; do not use any phone in the area.**
- **Leave the area immediately.**
- **Immediately call your fuel supplier. Follow the fuel supplier's instructions.**
- **If you cannot reach your fuel supplier, call the fire department.**

– **Installation and service must be performed by a qualified installer, service agency or the fuel supplier.**

The front cover shall include a statement informing users that they must read all instructions in the manual, and must keep all manuals for future reference.

b. Safety Section:

A safety section shall be included near the front of the manual to present hydrogen generator users with a listing of potential hazards and safety related instructions for a particular hydrogen generator. Statement of at least the following shall be included in the safety section with references to specific section or page of the manual.

1. Directions that the area surrounding the hydrogen generator must be kept clear and free of combustible materials, gasoline and other flammable vapours and liquids.

2. Where requiring air for combustion or ventilation, instructions not to block or obstruct air openings on the hydrogen generator, air openings communicating with the area in which the hydrogen generator is installed, and the required spacings around the hydrogen generator that provide clearances to secure and discharge required air.

3. Instructions for starting and shutting down the hydrogen generator. These instructions shall pictorially illustrate and locate all user interface components.

4. The following statement: "Do not use this hydrogen generator if any part has been under water. A flood-damaged hydrogen generator is potentially dangerous. Attempts to use the hydrogen generator can result in fire or explosion. A qualified service agency

should be contacted to inspect the hydrogen generator and to replace all gas controls, control system parts, electrical parts that have been wet.

5. Specifications for the frequency of filter change or cleaning and the dimensional size and type of filter for replacements. These instructions shall contain directions for removal and replacement of filters and pictorially illustrate and locate all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters.

6. Recommended methods for periodic cleaning of necessary parts.

7. Instructions for examining the hydrogen generator installation to determine that:

   a. Any intake or exhaust openings associated with those items covered in 1.9 are clear and free of obstructions.

   b. The physical support of the hydrogen generator is sound without sagging cracks, gaps, etc, around the base so as to provide a seal between the support and the base.

   c. There are no obvious signs of deterioration of the hydrogen generator.

8. The manual shall indicate the necessity and minimum frequency for the examination in "7" above by the user and shall also specify the periodic inspection of the hydrogen generator by a qualified service agent.

c. In-Text Safety Information:

In-text safety instructions should refer to or incorporate safety precautions from the front cover and from the safety section of the manual. Potentially hazardous situations described in the manual require that additional safety precautionary statements be created.

6.4.4 Operating manual

The operating manual shall detail proper procedures for set-up and use of the hydrogen generator. Particular attention should be given to the safety measures provided and to the improper methods of operation that are anticipated.

The operation manual shall include a section on the hazards related to the use of the hydrogen generator. As a minimum, the hazards related to the presence of hydrogen and the hazards related to the use of purge gases (if available) shall be covered.

Where the operation of equipment can be programmed, detailed information on methods of programming, equipment required, program verification and additional safety procedures (where required) shall be provided. The instructions shall give information concerning airborne noise emissions by the hydrogen generator, either the actual value or a value established on the basis of measurements made on identical hydrogen generator:

If the manufacturer foresees that the hydrogen generator will be used in a potentially explosive atmosphere, the instructions shall give all the necessary information.

In the case of the hydrogen generator which may also be intended for use by non-professional operators, the wording and layout of the instructions for use, whilst respecting the other essential requirements mentioned above, shall take into account the level of general education and acumen that can reasonably be expected from such operators.

Remote monitoring system

If the hydrogen generator is provided with a remote monitoring system, the manufacturer shall supply the procedures to address the changes to this remote monitoring system. The procedures shall address the following points where:

a) there is a person in charge at the hydrogen generator location;

b) there is no person in charge at the hydrogen generator location.

The procedures shall, as a minimum address the following points:

a) Modifying control parameters remotely;

b) Certifying an upgrade to the remote monitoring system;

c) Upgrading software remotely;

d) Certifying a parameter change;

e) Changing parameters remotely;

f) Uploading parameters;

g) Uploading software;

h) Qualifying the operation;

i) Undoing/reversing all changes;

j) Testing and backup documentation.

6.4.5 Maintenance manual

The maintenance manual shall detail proper procedures for adjustment, servicing, and preventive inspection, and repair. Recommendations on maintenance/servicing records should be part of the maintenance manual. Where methods for the verification of proper operation are provided (e.g. software testing programs), the use of such methods shall be detailed.

- This manual shall contain clearly defined, legible and complete instructions for at least the following:
- Instructions for starting and shutting down the hydrogen generator. These instructions shall pictorially illustrate and locate all components.
- Specifications for the frequency of filter change or cleaning and the dimensional size and type of filter for replacements. These instructions shall contain directions for removal and replacement of filters and pictorially illustrate and locate all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters.
- Recommended methods for periodic cleaning of necessary parts.
- Instructions for lubrication of moving parts, including type, grade and amount of lubricant.
- Instructions for examining the hydrogen generator installation to determine that:

  a) Any intake or exhaust openings are clear and free of obstructions.

  b) There are no obvious signs of physical deterioration of the hydrogen generator or its support (i.e. base, frame, cabinet, etc.).

- Periodic examination of the venting system and all functional parts.
- A parts list, including information necessary for ordering spare or replacement parts.

The maintenance manual shall also provide an enumeration of all regular and routine maintenance activities to be performed on the hydrogen generator components and indicate the necessity and minimum frequency for these examinations. The maintenance manual shall specify the periodic inspection of the hydrogen generator that shall be performed by qualified service personnel.

Appendix 1. Table of significant hazards, hazardous situations and events dealt with in this standard.

("Section" column to be completed)

Significant hazards, hazardous situations and events	Section
□ **Mechanical hazards due to:**	
□ Shape (sharp surfaces)	4.3
□ Relative location (trip/crash hazard)	4.3
□ Mass and stability (potential energy of elements which may move under the effect of gravity)	4.3
□ Mass and velocity (kinetic energy of elements in controlled or uncontrolled motion)	4.3, 4.12
□ Inadequacy of mechanical strength (inadequate specification of material or geometry)	4.3, 4.5, 4.13
□ Fluids under pressure (overpressurization, ejection of fluids under pressure, vacuum)	4.3, 4.5
□ **Electrical hazards due to:**	
□ Contact of persons with live parts (direct contact)	4.7
□ Contact of persons with parts that have become live under faulty conditions (indirect contact)	4.7
□ Approach to live parts under high voltage	4.7
□ Electrostatic phenomena	4.6, 4.7
□ Electromagnetic phenomena	4.8
□ Heat/ chemical effects from short circuits, overloads	4.7
□ Projection of molten particles	4.7
□ **Thermal hazards due to:**	
□ Contact of persons with surfaces at extreme high temperatures	4.3
□ Release of high temperature fluids	4.5
□ Thermal fatigue	4.4, 4.5
□ Equipment overtemperature causing unsafe operation	4.9
□ **Hazards generated by materials and substances:**	
□ Hazards from contact with or inhalation of harmful fluids, gases, mists, fumes and dusts.	4.3
□ Fire or explosion hazard due to leak of flammable fluids	4.6

□ Fire or explosion hazard due to internal build-up of flammable mixture	4.6
□ Hazardous situations caused by material deterioration (e.g. corrosion) or accumulation (e.g. fouling)	4.4
□ Asphyxiation	4.3
□ Reactive Materials (pyrophoric)	4.3
□ **Hazards generated by malfunctions:**	
□ Unsafe operation due to failures or inadequacy of software or control logic	4.9
□ Unsafe operation due to failures of control circuit or protective / safety components	4.9
□ Unsafe operation due to power outage	4.9
□ **Hazards generated by neglecting ergonomic principles**	
□ Hazards due to inadequate design, location or identification of manual controls	4.9
□ Hazards due to inadequate design or location of visual display units and warning signs	4.9
□ Noise	4.3
□ **Hazards generated by erroneous human intervention**	
□ Hazards due to deviation from correct operating	4.9, 6.4
□ Hazards due to errors of manufacturing/fitting/installation	4.3, 6.4
□ Hazards due to errors of maintenance	6.4
□ Vandalism	4.13
□ **Environmental Hazards:**	
□ Unsafe operation in extreme hot/cold environments	4.13
□ Rain, flooding	4.13
□ Wind	4.13
□ Earthquake	4.3
□ External Fire	
□ Smoke	
□ Snow, ice load	4.13
□ Attack by vermin	4.13
□ **Pollution:**	
□ Air pollution	4.3

□ Water pollution	4.3, 4.5
□ Soil pollution	4.3

Appendix 2. Carburisation and Material Compatibility for Hydrogen Service

(This Appendix is informative and is not part of the standard.)

A2.1 Carburisation

Conventional carburisation is a familiar problem with high-temperature alloys in steam reforming furnaces. It is caused by the inward migration of carbon, the source of which is hydrocarbon cracking, resulting in the formation of carbides within the metal matrix. The process is promoted by high temperature, typically > 800 ^{o}C , and leads ultimately to loss of ductility.

In general carburisation of an alloy results in low ductility at ambient temperatures. Carbon pickup will increase the volume of the metal and coefficient of expansion, resulting in strong internal stresses that give rise to premature failure of equipment. Failure is usually by creep rupture and low-cycle fatigue. If carburisation is sufficiently severe it can also affect the elevated temperature creep and rupture characteristics. There seems to be differences in tolerance between the various alloys regarding this issue.

Generally the carburisation rate varies with:

Temperature – The rate roughly doubles for every 55^{o}C increase.

Reaction kinetics is controlled by the ratio of CO/CO_2 in the gas and by the temperature. A CO/CO_2 ratio of t results in extremely severe attack, while a ratio of 0.5 yields insignificant attack.

Strongly carburising conditions are $CO/CH_4/H_2$-flows with a low steam/carbon ratio at intermediate temperatures (usually 450 – 850^{o}C), and an oxide layer with flaws.

Nickel and silicon content – High values are beneficial

Protective and regenerative oxide films – Cr, Si and Al in the alloy are beneficial.

These rules are general and may not be true for all material/environment combinations due to the anomalous character of metal reactions.

A2.2 Material Compatibility for Hydrogen Service

Components in which gaseous hydrogen or hydrogen-containing fluids are processed, as well as all parts used to seal or interconnect the same, should be sufficiently resistant to the chemical and physical action of hydrogen at the operating conditions.

A2.2.1 Metals and Metallic Materials

Users of this standard should be aware that engineering materials exposed to hydrogen in their service environment may exhibit an increased susceptibility to hydrogen assisted corrosion via different mechanisms such as hydrogen embrittlement and hydrogen attack.

Hydrogen embrittlement is defined as a process resulting in a decrease of the toughness or ductility of a metal due to the permeation of atomic hydrogen.

Hydrogen embrittlement has been recognized classically as being of two types. The first, known as internal hydrogen embrittlement, occurs when the hydrogen enters the metal matrix through material processing techniques and supersaturates the metal with hydrogen. The second type, environmental hydrogen embrittlement, results from hydrogen being absorbed by solid metals from the service environment.

Atomic hydrogen dissolved within a metal interacts with the intrinsic defects of the metal typically increasing crack propagation susceptibility and thus degrading such basic properties as ductility and fracture toughness.

There are both important material and environmental variables that contribute to hydrogen-assisted fracture in metals. The material microstructure is an important consideration as second phases, which may or may not be present due to compositional and processing variations, may affect the resistance of the metal to fracture. Second phases, such as ferrite stringers in austenitic stainless steels, may also have a specific orientation leading to profound anisotropic response in the materials. In general, metals can also be processed to have a wide range of strengths, and the resistance to hydrogen-assisted fracture is known to decrease as the strength of the alloy is increased.

The environmental variables affecting hydrogen-assisted fracture include pressure of hydrogen, temperature, chemical environment and strain rate. In general, the susceptibility to hydrogen-assisted fracture increases as hydrogen pressure increases. The effect of temperature, however, is not as systematic. Some metals such as austenitic stainless steels exhibit a local maximum in hydrogen-assisted fracture susceptibility as a function of temperature. Although not well understood, trace gases mixed with the hydrogen gas can also affect hydrogen-assisted fracture. Moisture, for example, may be detrimental to aluminum alloys since wet oxidation produces high-fugacity hydrogen, while in some steels moisture is believed to improve resistance to hydrogen-assisted fracture by producing surface films that serve as kinetic barriers to hydrogen uptake. A so-called inverse strain rate effect is generally observed in the presence of hydrogen; in other words, metals are less susceptible to hydrogen-assisted fracture at high strain rates.

At temperatures close to ambient this phenomenon can affect metals with body centered cubic crystal lattice structure, e.g. ferritic steels. In the absence of residual stress or external loading, environmental hydrogen embrittlement is manifested in various forms, such as blistering, internal cracking, hydride formation, and reduced ductility. With a tensile stress or stress-intensity factor exceeding a specific threshold, the atomic hydrogen interacts with the metal to induce sub-critical crack growth leading to fracture.

Hydrogen embrittlement can occur during elevated-temperature thermal treatments and in service during electroplating, contact with maintenance chemicals, corrosion reactions, cathodic protection, and operating in high-pressure, high temperature hydrogen.

At temperatures above 473°C, many low-alloyed structural steels may suffer from hydrogen attack. This is a non-reversible degradation of the steel microstructure caused by a chemical reaction between diffusing hydrogen and the carbide particles in the steels that results in the nucleation, growth and merging of methane bubbles along grain boundaries to form fissures.

Hydride embrittlement occurs in metals such as titanium and zirconium and is the process of forming thermodynamically stable and relatively brittle hydride phases within the structure.

Clad welding and welds between dissimilar materials often involve high alloy materials. During operation at temperatures over 250°C hydrogen diffuses in the fusion line between the high alloy weld and the unalloyed/ low alloy base material. During shutdown, the material temperature drops. The reduced solubility and diffusibility of hydrogen breaks the weld by disbonding.

The following are some general recommendations for managing the risk of hydrogen embrittlement.

- Select raw materials with a low susceptibility to hydrogen embrittlement by controlling chemistry (e.g. use of carbide stabilizers), microstructure (e.g. use of austenitic stainless steels), and mechanical properties (e.g. restriction of hardness, preferably below 225 HV, and minimization of residual stresses through heat treatment). Use test methods specified in ISO/DIS 11114-4 to select metallic materials resistant to hydrogen embrittlement. The API Publication 941 shows the limitations of various types of steel as a function of hydrogen pressure and temperature. The susceptibility to hydrogen embrittlement of some commonly used metals is summarized in ISO/PDTR 15916.

- Clad welds and welds between dissimilar materials used in hydrogen service should be ultrasonically tested at regular intervals and after uncontrolled shutdowns in which the equipment may have cooled rapidly.

- Minimize the level of applied stress and exposure to fatigue situations.

- When plating parts, manage anode/cathode surface area and efficiency, resulting in proper control of applied current densities. High current densities increase hydrogen charging.

- Clean the metals in non-cathodic alkaline solutions and in inhibited acid solutions.

- Use abrasive cleaners for materials having a hardness of 40 HRC or above.

- Use process control checks, when necessary, to mitigate risk of hydrogen embrittlement during manufacturing.

A2.2.2 Polymers, Elastomers, and other non-metallic materials

Most polymers can be considered suitable for gaseous hydrogen service. Due account should be given to the fact that hydrogen diffuses through these materials much easier than through metals. Polytetrafluoroethylene (PTFE or Teflon®) and Polychlorotrifluoroethylene (PCTFE or Kel-F®) are generally suitable for hydrogen service. Suitability of other materials should be verified. Guidance can be found in ISO/PDTR 15916 and the NASA document NSS 1740.16. See also ANSI/AGA 3.1-1995 for guidance with regard to gaskets, diaphragms, and other non-metallic parts.

Further guidance on hydrogen assisted corrosion and control techniques may be found through the following standards and organizations:

American Society for Testing and Materials

ASTM **B577-93** 01-Apr-1993
Standard Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper

ASTM **B839-94** 01-Nov-1994
Standard Test Method for Residual Embrittlement in Metallic Coated, Externally Threaded Articles, Fasteners, and Rod-Inclined Wedge Method

ASTM **B849-94** 01-Nov-1994
Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement

ASTM **B850-98** 01-Nov-1998
Standard Guide for Post-Coating Treatments Steel for Reducing the Risk of Hydrogen Embrittlement

ASTM **E1681-99** 10-Apr-1999
Standard Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials

ASTM **F1459-93** 01-Nov-1993
Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement

ASTM **F1624-00** 01-Aug-2000
Standard Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

ASTM **F1940-01** 01-Nov-2001
Standard Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners

ASTM **F2078-01** 01-Nov-2001
Standard Terminology Relating to Hydrogen Embrittlement Testing

ASTM **F326-96** 01-Nov-1996
Standard Test Method for Electronic Measurement for Hydrogen Embrittlement from Cadmium-Electroplating Processes

ASTM **F519-97** 01-Nov-1997
Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating Processes and Service Environments

ASTM **G129-00** 01-Aug-2000
Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking

ASTM **G142-98** 01-Nov-1998
Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature, or Both

ASTM **G146-01** 01-Feb-2001
Standard Practice for Evaluation of Disbonding of Bimetallic Stainless Alloy/Steel Plate for Use in High-Pressure, High-Temperature Refinery Hydrogen Service

ASTM **G148-97** 01-Nov-1997
Standard Practice for Evaluation of Hydrogen Uptake, Permeation, and Transport in Metals by an Electrochemical Technique

The National Association of Corrosion Engineers

NACE TM0177-96 23-Dec-1996
Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking in Hydrogen Sulfide (H2S) Environments

NACE TM0284-96 30-Mar-1996
Standard Test Method - Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

The American Petroleum Institute

API **RP 941** 01-Jan-1997
Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants.

API **934** 01-Dec-2000
Materials and Fabrication Requirements for 2-1/4Cr-1Mo & 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High Temperature, High Pressure Hydrogen Service

American Welding Society

ANSI/AWS A4.3-93 01-Jan-1993
Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding

The American Society of Mechanical Engineers

ASME Boiler and Pressure Vessel Code

ASME/ANSI B31.3 Chemical plant and petroleum refinery piping

ASME/ANSI B31.1 Power piping.

Society of Automotive Engineers

SAE/AMS 2451/4 01-Jul-1998
Plating, Brush, Cadmium - Corrosion Protective, Low Hydrogen Embrittlement

SAE/AMS 2759/9 01-Nov-1996
Hydrogen Embrittlement Relief (Baking) of Steel Parts

SAE/USCAR 5 01-Nov-1998
Avoidance of Hydrogen Embrittlement of Steel

International Standards Organization

ISO **15330** 01-Oct-1999
Fasteners -- Preloading test for the detection of hydrogen embrittlement -- Parallel bearing surface method

ISO **15724** 01-Jan-2001
Metallic and other inorganic coatings - Electrochemical measurement of diffusible hydrogen in steels - Barnacle electrode method

ISO **2626** 01-Oct-1973
Copper - Hydrogen embrittlement test

ISO **3690** 01-Mar-2000
Welding and allied processes -- Determination of hydrogen content in ferritic steel arc weld metal

ISO **3690 /Amd1** 01-Jan-1983
Amendment 1 - Welding - Determination of Hydrogen in Deposited Weld Metal Arising from the Use of Covered Electrodes for Welding Mild and Low Alloy Steels

ISO **7539-6** 1989
Corrosion of metals and alloys – Stress corrosion testing - Part 6: Preparation and use of pre-cracked specimens

ISO **9587** 01-Oct-1999
Metallic and other inorganic coatings -- Pretreatments of iron or steel to reduce the risk of hydrogen embrittlement

ISO **9588** 01-Oct-1999
Metallic and other inorganic coatings -- Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement

ISO **PDTR 15916** 09-May-2002
Basic considerations for the safety of hydrogen systems

ISO/DIS **11114-4** 2003-07-15
Transportable gas cylinders – Compatibility of cylinders and valve materials with gas contents – Part 4: Test methods for hydrogen compatibility with metals

European Standards

BS 7886 01-Jan-1997
Method of Measurement of Hydrogen Permeation and the Determination of Hydrogen Uptake and Transport in Metals by an Electrochemical Technique

DIN **8572-1** 01-Mar-1981
Determination of Diffusible Hydrogen in Weld Metal - Manual Arc Welding

DIN **8572-2** 01-Mar-1981
Determination of Diffusible Hydrogen in Weld Metal - Submerged Arc Welding

Appendix 3: Recycling of hydrogen generators

(This Appendix is informative and is not part of the standard.)

Recycling of hydrogen generator's hardware depends on issues such as materials selection, hardware accessibility, and ease of materials separation.

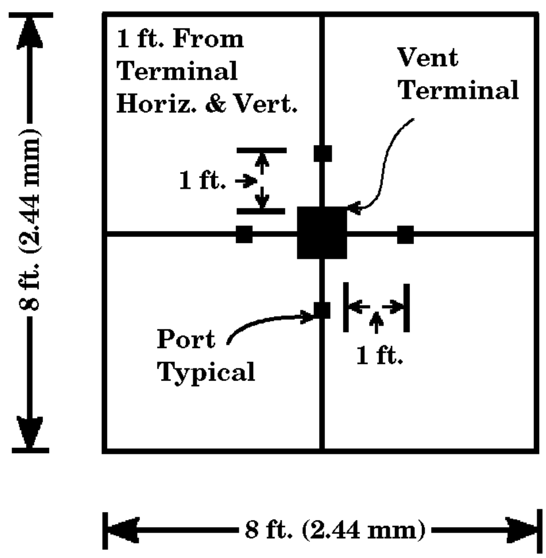
System Components and Material Types

The hydrogen generator's hardware will generally be carried out within metallic vessels, commonly made of corrosion-resistant, high alloy nickel chromium steel, which house the catalysts, commonly precious metal based. The catalyst composition will be determined by the specific processing operation, however from a recycling standpoint we can say the following. When the economics of catalyst metals recovery is sufficiently attractive, there will be an incentive to recover the catalyst from inside the vessel for the purpose of extracting and recycling the metal. High temperature ceramic insulation made from alumina, silica, and/or zirconia is typically installed internal to the steel vessel. Zinc oxide sorbent, used to remove sulfur from the fuel is converted to zinc sulfide and accumulated in the unit until it can be removed and disposed. Activated carbon may also be used to remove sulfur from the fuel stream. Hydrogen-selective permeable metal membranes of Pd, PdAg and other Pd alloys contained within a steel vessel is an alternative to the use of discrete components for desulfurization, water-gas shift, and selective oxidation

Recycling Engineering and Environmental Issues

For ease in materials recycling, vessels should be designed to enable precious metals removal and ease in material separation. It is expected that the steel components will be recycled using existing recycling technology. Access to catalyst contained within the vessels should be possible if catalyst recycling is planned. Currently, nickel catalyst with a metal content of more than 20 percent or precious metal catalyst can be economically recycled using existing processes.

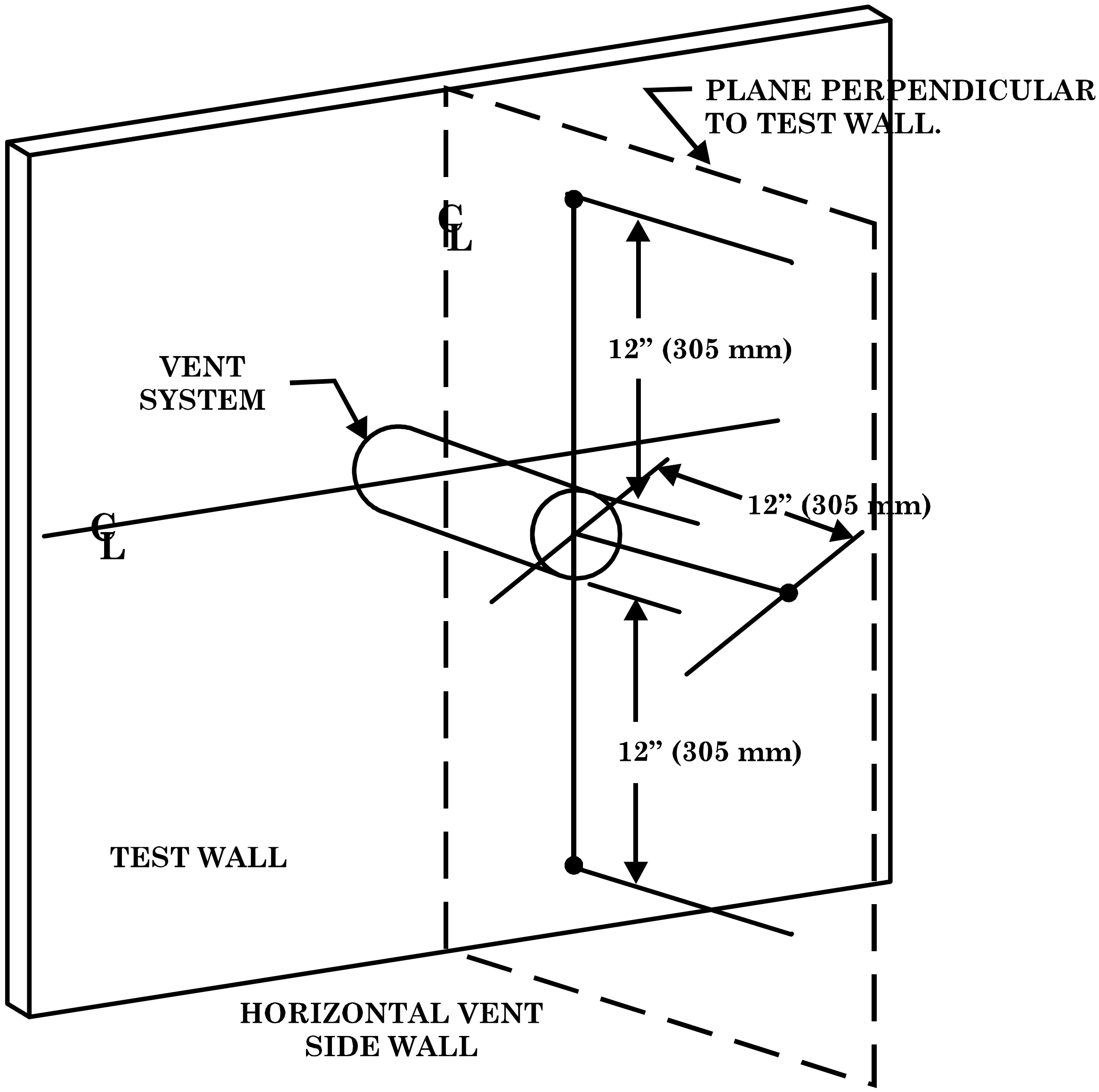
Appendix 4 - Figure: Test Wall with Static Pressure Ports and Vent Terminal Locations



Points Designate Static Pressure Ports Located 1 Foot (305 mm) Horizontally and Vertically from the Extremities of the Vent Terminal

Vent Terminal Located in Center of Test Wall and in Accordance With Manufacturers Installation Instructions

Appendix 5 - Figure: Vent Test Wall



Appendix 6: Figure - Piezo Ring and Details of Typical Construction