INTERNATIONAL STANDARD

ISO 22734-1

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Hydrogen generators using water electrolysis process —

Part 1: Industrial and commercial applications

Générateurs d'hydrogène utilisant le procédé de l'électrolyse de l'eau —

Partie 1: Applications industrielles et commerciales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22734-1 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

ISO 22734 consists of the following parts, under the general title *Hydrogen generators using water electrolysis process*:

— *Part 1: Industrial and commercial applications*

— *Part 2: Residential applications*

0 Introduction

0.1 Electrolysis Technology

In an electrolyser cell, electricity causes dissociation of water into hydrogen and oxygen molecules. An electric current is passed between two electrodes separated by a conductive electrolyte or “ion transport medium”, producing hydrogen at the negative electrode (cathode) and oxygen at the positive electrode (anode). As water is H_2O, twice the volume of hydrogen is produced over oxygen. Hydrogen gas produced using electrolysis technology can be utilized immediately or stored for later use.

The cell(s), and electrical, gas processing, ventilation, cooling and monitoring equipment and controls are contained within the hydrogen generator enclosure. Gas compression and feed water conditioning and auxiliary equipment may also be included.

Hydrogen generators using water electrolysis process —

Part 1: Industrial and commercial applications

1 Scope

This International Standard defines the construction, safety and performance requirements of packaged or factory matched hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyse water to produce hydrogen and oxygen gas.

This International Standard is applicable to hydrogen generators that use the following types of ion transport medium:

— Group of aqueous bases;

— Solid polymeric materials with acidic function group additions such as acid proton exchange membrane (PEM).

This part of ISO 22734 is applicable to hydrogen generators intended for indoor and outdoor commercial and industrial use (non-residential use). Hydrogen generators that can also be used to generate electricity such as reversible fuel cells are excluded from the scope of this International Standard.

This International Standard is intended to be used for certification purposes.

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.

ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO 1182, *Reaction to fire tests for building products — Non-combustibility test*

ISO 3864 (all parts), *Graphical symbols — Safety colours and safety signs*

ISO 4126-1, *Safety devices for protection against excessive pressure — Part 1: Safety valves*

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

ISO 4706, *Refillable welded steel gas cylinders*

ISO 7866, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

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

ISO 9809-1, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

ISO 9809-2, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

ISO 9809-3, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*

ISO 9951, *Measurement of gas flow in closed conduits — Turbine meters*

ISO 10790, *Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis meters (mass flow, density and volume flow measurements)*

ISO 11119-1, *Gas cylinders of composite construction — Specification and test methods — Part 1: Hoop wrapped composite gas cylinders*

ISO 11119-2, *Gas cylinders of composite construction — Specification and test methods — Part 2: Fully wrapped fibre reinforced composite gas cylinders with load-sharing metal liners*

ISO 11119-3, *Gas cylinders of composite construction — Specification and test methods — Part 3: Fully wrapped fibre reinforced composite gas cylinders with non-load-sharing metallic or non-metallic liners*

ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles*

ISO 12499, *Industrial fans — Mechanical safety of fans — Guarding*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

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

ISO 13852, *Safety of machinery — Safety distances to prevent danger zones being reached by the upper limbs*

ISO 13853, *Safety of machinery — Safety distances to prevent danger zones being reached by the lower limbs*

ISO 13854, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

ISO 14121-1, *Safety of machinery — Risk assessment — Part 1: Principles*

ISO 14511, *Measurement of fluid flow in closed conduits — Thermal mass flowmeters*

ISO 14687, *Hydrogen fuel — Product specification*

ISO 14847, *Rotary positive displacement pumps — Technical requirements*

ISO 15534-1, *Ergonomic design for the safety of machinery — Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery*

ISO 15534-2, E*rgonomic design for the safety of machinery — Part 2: Principles for determining the dimensions required for access openings*

ISO 15649, *Petroleum and natural gas industries — Piping*

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

ISO 16528-1, *Boilers and pressure vessels — Part 1: Performance requirements*

ISO 17398, *Safety colours and safety signs — Classification, performance and durability of safety signs*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60068-2-18:2000, *Environmental testing — Part 2-18: Tests — Test R and guidance: Water*

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

IEC 60079-2:2007: *Explosive atmospheres — Part 2: Equipment protection by pressurized enclosures "p"*

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*

IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*

IEC 60079-29-1, *Explosive atmospheres — Part 29-1: Gas detectors — Performance requirements of detectors for flammable gases*

IEC 60079-29-2, *Explosive atmospheres — Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen*

IEC 60079-30-1, *Explosive atmospheres — Part 30-1: Electrical resistance trace heating — General and testing requirements*

IEC 60146 (all parts), *Semiconductor convertors*

IEC 60204-1:2005, *Safety of machinery - Electrical equipment of machines — Part 1: General requirements*

IEC 60335-2-30, *Household and similar electrical appliances — Safety — Part 2-30: Particular requirements for room heaters*

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 60335-2-73, *Household and similar electrical appliances — Safety — Part 2-73: Particular requirements for fixed immersion heaters*

IEC 60335-2-74, *Household and similar electrical appliances — Safety — Part 2-74: Particular requirements for portable immersion heaters*

IEC 60335-2-80, *Household and similar electrical appliances — Safety — Part 2-80: Particular requirements for fans*

IEC 60364-4-43, *Electrical installations of buildings — Part 4-43: Protection for safety — Protection against overcurrent*

IEC 60364-6:2006, *Low-voltage electrical installations — Part 6 : Verification*

IEC 60439-1, *Low-voltage switchgear and controlgear assemblies — Part 1: Type-tested and partially type-tested assemblies*

IEC 60439-2, *Low-voltage switchgear and controlgear assemblies — Part 2: Particular requirements for busbar trunking systems (busways)*

IEC 60439-3, *Low-voltage switchgear and controlgear assemblies — Part 3: Particular requirements for low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use — Distribution boards*

IEC 60439-5, *Low-voltage switchgear and controlgear assemblies — Part 5: Particular requirements for assemblies for power distribution in public networks*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals and conductor terminations*

IEC 60446, *Basic and safety principles for man-machine interface, marking and identification — Identification of conductors by colours or alphanumerics*

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

IEC 60534 (all parts), *Industrial-process control valves*

IEC 60695-11-10, *Fire hazard testing — Part 11-10: Test flames — 50 W horizontal and vertical flame test methods*

IEC 60695-11-20, *Fire hazard testing — Part 11-20: Test flames — 500 W flame test methods*

IEC 60730-1:2007, *Automatic electrical controls for household and similar use — Part 1: General requirements*

IEC 60747 (all parts), *Semiconductor devices — Discrete devices*

IEC/TR 60877, *Procedures for ensuring the cleanliness of industrial-process measurement and control equipment in oxygen service*

IEC 60947-2, *Low-voltage switchgear and controlgear — Part 2: Circuit-breakers*

IEC 60947-3, *Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-4-1, *Low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters*

IEC 60947-4-2, *Low-voltage switchgear and controlgear — Part 4-2: Contactors and motor-starters — AC semiconductor motor controllers and starters*

IEC 60947-4-3, *Low-voltage switchgear and controlgear — Part 4-3: Contactors and motor-starters — AC semiconductor controllers and contactors for non-motor loads*

IEC 60947-5-1, *Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

IEC 60947-5-2, *Low-voltage switchgear and controlgear — Part 5-2: Control circuit devices and switching elements — Proximity switches*

IEC 60947-5-3, *Low-voltage switchgear and controlgear — Part 5-3: Control circuit devices and switching elements — Requirements for proximity devices with defined behaviour under fault conditions (PDF)*

IEC 60947-5-5, *Low-voltage switchgear and controlgear — Part 5-5: Control circuit devices and switching elements — Electrical emergency stop device with mechanical latching function*

IEC 60947-6-1, *Low-voltage switchgear and controlgear — Part 6-1: Multiple function equipment — Transfer switching equipment*

IEC 60947-6-2, *Low-voltage switchgear and controlgear — Part 6-2: Multiple function equipment — Control and protective switching devices (or equipment) (CPS)*

IEC 60947-7-1, *Low-voltage switchgear and controlgear — Part 7-1: Ancillary equipment — Terminal blocks for copper conductors*

IEC 60947-7-2, *Low-voltage switchgear and controlgear — Part 7-2: Ancillary equipment — Protective conductor terminal blocks for copper conductors*

IEC 60950-1:2005/Cor. 1:2006, *Information technology equipment — Safety — Part 1: General requirements*

IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003, *Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements*

IEC 61069-7, *Industrial-process measurement and control — Evaluation of system properties for the purpose of system assessment — Part 7: Assessment of system safety*

IEC 61131-1, *Programmable controllers — Part 1: General information*

IEC 61131-2, *Programmable controllers — Part 2: Equipment requirements and tests*

IEC 61204, *Low-voltage power supply devices, d.c. output — Performance characteristics*

IEC 61204-6, *Low-voltage power supplies, d.c. output — Part 6: Requirements for low-voltage power supplies of assessed performance*

IEC/TR 61459, *Coordination between fuses and contactors/motor-starters — Application guide*

IEC 61508-1, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 1: General requirements*

IEC 61508-2, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems*

IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems — Part 3: Software requirements*

IEC 61511-1, *Functional safety — Safety instrumented systems for the process industry sector — Part 1: Framework, definitions, system, hardware and software requirements*

IEC 61558 (all parts), *Safety of power transformers, suppIlies, reactors and similar products (all applicable parts)*

IEC 61558-2-17, *Safety of power transformers, power supply units and similar — Part 2-17: Particular requirements for transformers for switch mode power supplies*

3 Terms and definitions

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

3.1
area classification
classification of hazardous areas according to the probability of the existence of an explosive gas-air atmosphere, in order to relate the selection of electrical apparatus for use in the area to the degree of hazard

3.2
classified area
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

3.3
commercial
relating to the use of hydrogen generators by laymen in non-manufacturing business facilities such as stores, hotels, office buildings, educational institutes, filling stations, warehouses, and other non-residential locations

3.4
containment system
part of the apparatus containing a flammable substance that may constitute a source of release

3.5
design pressure
pressure value applied to the design of pressure containing components, which represents the pressure at the most severe condition of coincident internal or external pressure and temperature expected during service

NOTE Design pressure is represented in Annex B.

3.6
design temperature
temperature value applied to the design of pressure containing components; the temperature at the most severe condition of coincident pressure expected during service

3.7
dilution
continuous supply of a purge gas at such a rate that the concentration of a flammable substance inside an enclosure is maintained at a value outside the explosive (flammable) limits at any potential ignition source (that is to say, outside the dilution area)

3.8
dilution volume
area in the vicinity of a source of release where the concentration of flammable substance is not diluted to a level below the lower flammability limit (LFL)

NOTE 1 Dilution of oxygen by inert gas may result in a concentration of flammable gas or vapour above the upper flammability limit (UFL).

NOTE 2 Annex C provides information on the flammability limits of hydrogen.

3.9
enclosure
containment and support structure(s) protecting a hydrogen generator from specific environmental and climatic conditions and protecting persons and livestock from incidental contact with the hazardous parts of the hydrogen generator

3.10
enriched oxygen atmosphere
gas that contains a volume fraction of more than 23,5 % oxygen with the remainder of its components being inert

3.11
hazardous condition
condition that may adversely affect safety of the hydrogen generator operation

NOTE Examples of hazardous conditions include having an enriched oxygen atmosphere, a hydrogen concentration exceeding the lower flammability limit, an ignition source in a classified area, an overpressure, an over temperature.

3.12
industrial
relating to the use of hydrogen generators by qualified and experienced personnel in a controlled manufacturing or processing environment

3.13
ion transport medium
medium that provides ionic transport within the cell

3.14
maximum normal operating pressure
maximum pressure that can be experienced by the pressure containing components when the hydrogen generator is functioning within its design and control parameters

NOTE Maximum normal operating pressure is represented in Annex B.

3.15
membrane
material that provides separation between oxygen and hydrogen product gases while allowing ionic transport within the cell

3.16
normal conditions
conditions to which the volume or other properties of a gas are referred and which are represented by a temperature of 273,15 K (0 °C) and an atmospheric pressure of 101,325 kPa

3.17
normal operating pressure
pressure that is experienced by the pressure bearing components when the hydrogen generator is functioning within its design and control parameters

3.18
pressure bearing component
part, which is subject to a minimum positive internal pressure of 50 kPa during normal operating conditions

3.19
purge gas
gas used to maintain pressurization or to dilute flammable gas or vapour to a concentration well below the lower flammability limit

3.20
purging
passage of sufficient volume of a purge gas through a pressurized enclosure and its ducts, before the application of voltage to the apparatus to reduce any ignitable (flammable) gas atmosphere to a concentration well below the lower flammability limit

3.21
storage cylinder
pressure container intended to store product gas

4 Operating conditions and specifications

4.1 Energy consumption

4.1.1 Electrical

The manufacturer shall specify as outlined in IEC 60204-1 the electrical input rating for the hydrogen generator in volts, amperes or watts (VA or W), and hertz.

4.1.2 Other utilities

The manufacturer shall specify other utilities required.

4.2 Feed water specifications

The manufacturer shall define the specification for the feed water to be used in the hydrogen generator.

4.3 Ambient environment

The manufacturer shall specify the physical environment conditions for which the hydrogen generator is designed. These shall include, as applicable, indoor or outdoor operation, the ambient temperature range, the barometric and humidity specifications and the seismic zone rating.

4.4 Purge gas

Where the use of purge gas is required, the manufacturer shall specify the type of purge gas and its specifications.

4.5 Oxygen storage/venting

The manufacturer shall specify if the oxygen produced by the hydrogen generator is to be stored, vented inside the hydrogen generator enclosure, vented indoor, or vented outdoor. If an oxygen port is provided, a label warning of enriched oxygen hazards shall be located near the port as requested by 11.6.

4.6 Delivery of hydrogen

The manufacturer shall specify the hydrogen production rate, the hydrogen output pressure range, the hydrogen temperature range, and the hydrogen quality as per in ISO 14687.

4.7 Delivery of oxygen

If oxygen is a specified product, the manufacturer shall specify the oxygen production rate, the oxygen output pressure range, the oxygen temperature range, and the quality of the oxygen produced by the hydrogen generator.

5 Mechanical equipment

5.1 General requirements

The manufacturer shall implement the measures and provide the information necessary to minimize the risk of endangering a person's safety or health as determined by a risk assessment performed in accordance with ISO 14121-1.

All hydrogen generator parts and all substances used in the hydrogen generator shall be,

— suitable for the range of temperatures and pressures to which the hydrogen generator is subjected during expected usage,

— resistant to the reactions, processes and other conditions to which the hydrogen generator is exposed during expected usage,

— suitable for their intended use, and

— used within their rating and as per the manufacturer's instructions.

The hydrogen generator shall be designed to withstand the expected shocks and vibration loads, as well as the specified ambient temperature range during transportation to the installation site and use. Means shall be provided to facilitate the safe handling of the hydrogen generator during lifting, moving and positioning operations. The hydrogen generator shall be designed to remain stable when subjected to normal operational forces imposed by operators or by the environment during the installation or use.

The design of the hydrogen generator shall take into account the requirements specified in ISO 12100-2.

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 protected.

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

All parts shall be protected from climatic and environmental conditions anticipated by the operating conditions such as seismic zone rating, snow and wind loading.

All parts shall be of such construction as to be secure against displacement, distortion, warping or other damage that could affect their functionality.

All parts that may be contacted during normal usage, adjustment or servicing shall be free from sharp projections or edges.

All parts that require regular or routine maintenance or servicing such as inspection, lubrication, cleaning, replacement or similar functions shall be accessible.

Moving parts and parts containing liquid shall be designed and mounted in such a way that in all modes of operation, the ejection of parts and spilling of liquid are prevented.

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

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 of these parts.

5.2 General materials requirements

Materials employed in the hydrogen generator shall be suitable for their purpose.

All internal and external parts of the hydrogen generator that are directly exposed to moisture, ion transport medium, process gas streams of hydrogen or oxygen as well as parts used to seal or interconnect the same shall have the following material attributes during the manufacturer's rated service life:

a) retain mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) when exposed to the full range of the operating conditions specified in Clause 4;

b) resist the chemical and physical action of the fluids that they contain and resist environmental degradation;

c) be compatible with any other material used in conjunction so as to not have a synergistic and undesirable effect.

When selecting materials and manufacturing methods, due consideration shall be given to:

- hydrogen embrittlement and hydrogen assisted corrosion as indicated in Annex A and in ISO/TR 15916;
- oxygen compatibility;
- corrosion and wear resistance;
- electrical conductivity;
- impact strength;
- aging resistance;
- temperature effects;
- galvanic corrosion;
- erosion, abrasion, corrosion or other chemical attack;
- resistance to ultraviolet (UV) radiation.

The auto-ignition temperature of any materials used in contact with oxygen under any conditions shall be at least 50 °C above the maximum operating temperature the material may be exposed to.

Process piping and vessels carrying oxygen shall be cleaned in accordance with IEC/TR 60877.

5.3 Enclosures

5.3.1 Minimum strength

The supporting structure and the hydrogen generator enclosure shall have the strength, the rigidity, the durability, the resistance to corrosion and the other physical properties to support and protect all the components and piping, and withstand mechanical stress and shock expected during transport, installation and operation of the hydrogen generator. Electrical enclosures shall meet the requirements of IEC 60204-1.

5.3.2 Environmental tolerance

The hydrogen generator enclosure shall be designed and tested for the intended installation environment as classified in IEC 60529. As a minimum, the hydrogen generator enclosure shall meet the IP 22 rating defined in IEC 60529.

Enclosures used in industrial environments or outdoors may need to meet higher IP classifications.

5.3.3 Fire resistance

Enclosures shall have a flammability classification as follows:

a) for enclosure materials other than plastics, the enclosure shall have a flammability classification that will not support accelerating combustion after electrical and fuel gas sources are removed. The enclosure shall comply with ISO 1182;

b) plastic enclosures that cover sources of combustion or enclose live parts shall comply with the requirements of 5V rated materials when tested according to IEC 60695-11-20. Other plastic enclosures shall comply with the requirements of HB and V rated materials when tested according to IEC 60695-11-10;

c) composite materials shall meet the requirements of either a) or b) above.

5.3.4 Insulating materials

Insulating materials on the hydrogen generator enclosure shall be mechanically or adhesively retained in place and shall be protected against displacement or damage from anticipated loads and service operation.

Insulating materials and their internal bonding or adhesive attachment means shall withstand all air velocities and temperatures to which they may be subjected in normal operation.

5.3.5 Access panels

Access panels shall be designed according to the requirements given in ISO 15534-1 and ISO 15534-2.

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.

An access panel, cover or door shall require the use of a tool, key or similar mechanical means to open.

Removable access panels, covers and doors shall be designed so as to prevent them from being attached in an improper position or being interchanged in a manner that may interfere with proper operation of the hydrogen generator.

5.3.6 Ventilation openings

Ventilation openings shall be designed so that they will not become obstructed during normal operation in accordance with the expected application.

Where personnel can fully enter the hydrogen generator enclosure, ventilation openings shall have a minimum total area of 0,003 m^2 per m^3 of enclosure volume.

5.3.7 Containment of hazardous liquid leakage

Where a hydrogen generator contains hazardous liquids that can be harmful to personnel or the environment, the hydrogen generator enclosure shall be designed to safely contain anticipated leaks as follows:

a) The containment means shall have a capacity of 110 % of the maximum volume of the anticipated leak;

b) A leak detector shall be fitted in the lowest area of the hydrogen generator enclosure where the leak would be expected to accumulate. The detector signal shall cause the hydrogen generator to alarm and where possible change the operating parameters to prevent further accumulation before 25 % of the maximum volume of the anticipated leak accumulates.

5.4 Pressure bearing components

5.4.1 General requirements

Special consideration shall be given to the following aspects of pressure bearing components:

a) support, constraint, anchoring, alignment and pre-tension techniques to mitigate excessive stresses and strains being produced on flanges, connections, bellows or hoses;

b) effects of sudden movement, for example, high-pressure jets, water hammer, pressure relieving device actuations;

c) means for drainage and cleaning of condensation during start-up and/or use occurring inside pressure bearing components for gaseous fluids which could cause damage from water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions;

d) precautions in design and marking where explosive, flammable, or toxic fluids might be contained.

5.4.2 Built-in storage of hydrogen and oxygen

5.4.2.1 Hydrogen storage cylinders

When used, built-in storage cylinders of pressurized gaseous hydrogen shall comply with one of the following types of cylinders:

a) aluminium cylinders meeting the requirements of ISO 7866;

b) steel cylinders meeting the requirements of ISO 9809-1;

c) hoop wrapped composite cylinders meeting the requirements of ISO 11119-1;

d) fully wrapped fibre reinforced composite gas cylinders with load-sharing metal liners meeting the requirements of ISO 11119-2;

e) fully wrapped fibre reinforced composite gas cylinders with non-load-sharing metallic liners or non-metallic liners meeting the requirements of ISO 11119-3;

f) vessels of appropriate construction meeting the requirements of ISO 16528-1 or an equivalent standard.

5.4.2.2 Oxygen storage cylinders

When used, built-in storage cylinders of gaseous oxygen shall comply with one of the following types of cylinder:

a) steel cylinders that meet the requirements of any one of:

— ISO 4706,

— ISO 9809-1,

— ISO 9809-2,

— ISO 9809-3;

b) vessels of appropriate construction meeting the requirements of ISO 16528-1 or an equivalent standard.

5.4.2.3 Separation of hydrogen and oxygen storage cylinders

Oxygen and hydrogen storage cylinders shall be separated by either:

a) a minimum distance of 3 m, or

b) a non-combustible partition with a 60 min fire rating as determined by ISO 834-1.

5.4.3 Cell stacks

Cell stacks shall be designed to withstand the cell stack pressure tests of 10.1.5 without rupture and permanent deformation.

5.4.4 Process vessels

Process vessels for fluids that may exceed 50 kPa in normal operation shall comply with one of the recognized standards conforming to ISO 16528-1 unless the size (diameter or volume) is less than the minimum of the scope of the referenced standards as applicable.

5.4.5 Piping, fittings and joints

Process piping, fittings and joints shall conform to one of the recognized standards conforming to ISO 16528-1 or the applicable piping standard of ISO 15649 with the following exception:

Polymeric or elastomeric piping, tubing and joints shall be allowed for flammable fluid service.

The internal surfaces of piping shall be thoroughly cleaned to remove loose particles greater than 10 µm, and the ends of piping shall be carefully finished to remove obstructions and burrs.

Threaded portions of piping and associated component parts that connect externally to the hydrogen generator shall have threads conforming to ISO 15649.

Polymeric or elastomeric piping, tubing and joints shall be suitable for the combined maximum operating temperature, pressure and chemical and material exposure anticipated in service and during maintenance. They shall be non-permeable if employed for flammable fluid service. Adequate mechanical strength shall be demonstrated through the pressure tests per 10.1.5.

Polymeric or elastomeric piping, tubing and joints shall be protected from mechanical damage within the hydrogen generator. Shielding may be used as appropriate to protect components against failure of rotating equipment or other mechanical devices housed within the hydrogen generator enclosure. Any compartment enclosing plastic or elastomeric components used to convey flammable fluids shall be protected against the possibility of overheating. Plastic or elastomeric materials used in classified areas shall prevent static build-up if conveying dry hydrogen gases as outlined in ISO 15649.

5.4.6 Compressors

If used, compressors shall be suitable for hydrogen or oxygen use, as applicable.

Compressors 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 pressure and temperature and low suction pressure;

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

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

5.4.7 Pressure relief devices

All pressurized systems and equipment shall be protected from overpressure by means of one or more pressure relief devices of the self-destructive type, such as rupture disks and diaphragms, or of the re-sealable type, such as spring-loaded pressure relief valves (PRV's).

Pressure relief devices shall be directly connected to the equipment, which is the potential source of overpressure with no interconnected isolation devices. In the event of a rupture disk failure, the hydrogen generator shall shut down.

Relieved gases that are vented within the hydrogen generator enclosure shall be vented into a classified area. Installation instructions shall be provided for the relieved gases that are vented outdoors or indoors (see 12.5).

Pressure relief valves shall meet the requirements of ISO 4126-1 or the standards conforming to ISO 16528-1. Rupture disks shall meet the requirements of ISO 4126-2 or one of the standards conforming to ISO 16528-1.

5.4.8 Pressure regulators

Pressure regulators shall be of the non-venting type or installation instructions shall be provided to ensure that the vents are piped to a safe location (see 12.5). Pressure regulators shall be suitable for hydrogen or oxygen use and for the pressures and temperatures that will be encountered.

Pressure regulator actuators controlled by a pneumatic power source shall not have a diaphragm that could leak air into hydrogen.

5.4.9 Shut-off valves

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, or emergency conditions.

Shut-off valves shall be rated for the pressures and temperatures encountered and shall be suitable for the fluid media. Actuators mounted on shut-off valves shall be temperature rated to withstand heat transferred from the valve body.

Automatically operated shut-off valves shall conform to IEC 60534.

Automatically operated shut-off valves shall be of a type that will go to a fail-safe position.

5.5 Electric heaters

Electric heaters, when provided for protection of equipment at low ambient temperatures, shall meet the requirements of IEC 60204-1 and shall conform, as applicable, to any one of the following International Standards: IEC 60335-2-73, IEC 60335-2-74 or IEC 60335-2-30.

When used in classified areas, heaters shall conform to IEC 60079-14.

5.6 Pumps

Pumps shall conform as applicable to ISO 13709, ISO 14847, IEC 60335-2-51, or IEC 60335-2-41.

The connection band between the motor and pump shall be made of antistatic material.

5.7 Fans and ventilators

Fans and ventilators shall conform to IEC 60335-2-80 or shall conform to ISO 12499 with the electrical requirements evaluated as per IEC 60204-1. Fans and ventilators shall be of a type suitable for the application.

5.8 Heat transfer system

Any means of heat transfer, commensurate with the chemistry of the affected fluids or gases, may be used.

5.9 Connection to potable water

If potable water is to be used as the feed-water, the hydrogen generator shall be provided with means to prevent any back feeding into the potable water supply.

In addition, means shall be provided to prevent any coolant from the heat transfer system from back feeding into the potable water supply.

6 Electrical equipment, wiring and ventilation

6.1 Fire and explosion hazard protection requirements

6.1.1 General requirements

Hydrogen generators shall be manufactured such that unintentional hydrogen releases during normal operation are precluded. Conformity shall be determined by the test of 10.2.5.

NOTE In operation, the potential volume of gas leakage is limited by the rate of gas production when there is no internal storage.

6.1.2 Area classification for hydrogen generators

The hydrogen generator enclosure shall be classified according to IEC 60079-10. Where appropriate, instructions shall be provided to define the classification and extent of classified areas surrounding the hydrogen generator as per IEC 60079-10 (see 12.5).

6.1.3 Protection requirements for equipment within classified areas

Equipment within classified areas shall comply with the requirements of IEC 60079-0 and the appropriate parts of IEC 60079 for the type(s) of protection used or IEC 60079-30-1.

When equipment is intended for operation under conditions that are not covered in the scope of the IEC 60079 International Standards or in the scope of IEC 60079-30-1 (e.g. operation in an enriched oxygen atmosphere), additional testing related specifically to the intended conditions of use shall be performed.

NOTE This is particularly important when the types of protection flameproof enclosures “d” (IEC 60079-1) and intrinsic safety “i” (IEC 60079-11) are applied.

6.1.4 Protection methods to prevent the accumulation of ignitable mixtures

Protection may be provided by passive or active means to ensure that gas mixtures remain below a volume fraction of 1 % hydrogen within the hydrogen generator enclosure, except in dilution volumes. Computational fluid dynamics analysis, tracer gas, or similar methods such as those given in IEC 60079-10, may be used to determine the 1 % volume fraction of hydrogen in air dilution boundary and ventilation requirements.

Passive methods include, but are not limited to:

a) pipe orifices and similar methods of flow restriction to restrict the maximum release rate to a predictable value;

b) use of joints that are permanently secured and constructed so that they limit the maximum release rate to a predictable value.

Active methods include, but are not limited to:

a) comparison of hydrogen gas flow or pressure measurements relative to control settings to initiate protective measures such as de-energization of non-classified electrical equipment and initiation of ventilation when an out-of-specification condition is detected;

b) constant ventilation sufficient to maintain an average hydrogen gas concentration within the hydrogen generator enclosure, except in dilution volumes, below the maximum volume fraction of 1 % hydrogen based on the maximum anticipated hydrogen gas leak rate into the hydrogen generator enclosure as determined by the manufacturer;

c) a hydrogen gas detection system complying with the requirements of 6.1.9 that initiates ventilation at a volume fraction of 0,4 % hydrogen.

When ventilation is used as an active protection means, the required minimum ventilation rate shall maintain a volume fraction of 1 % hydrogen based on the maximum anticipated hydrogen gas leak rate into the hydrogen generator enclosure as determined by the manufacturer.

NOTE Sudden and catastrophic failure of vessels or piping systems need not be considered a leak scenario in this analysis when protection against such failures has already been contemplated in the vessel and piping design.

When such active and/or passive protection measures are used, the area classification determined as per 6.1.2 and the protection requirements for electrical equipment as per 6.1.3 may be adjusted accordingly. Detection of hydrogen/air mixtures exceeding the maximum volume fraction of 1 % hydrogen shall cause hydrogen generation to stop and de-energization of non-classified electrical equipment. Failure of ventilation shall cause a shutdown of gas generation. Equipment that shall remain energized in the event of failure such as a hydrogen gas detection system and ventilation equipment shall be suitable for use in classified areas as per 6.1.3.

6.1.5 Additional protection measures for hydrogen generators where oxygen is purposely vented inside the hydrogen generator enclosure

When applicable, oxygen purposely vented inside the hydrogen generator enclosure shall be diluted sufficiently by a ventilation air stream to preclude a hazardous enriched oxygen atmosphere within the hydrogen generator enclosure. Classified electrical equipment that could come in contact with enriched oxygen mixtures shall be evaluated for their suitability under the possible conditions as indicated in 6.1.3.

The design of the ventilation shall dilute the oxygen concentration such that any gas flow exiting the hydrogen generator enclosure to the surrounding environment will not create a hazardous condition. Where mechanical ventilation is used to dilute oxygen levels, means of detecting insufficient air ventilation and causing hydrogen generator shutdown shall be provided.

6.1.6 Ventilation

Whenever ventilation is used as per 6.1.4 or 6.1.5, the manufacturer shall specify the ventilation rate and the operating pressure of the ventilation system.

Failure of ventilation shall cause a shutdown of gas generation.

6.1.7 Start-up purge

Hydrogen generator enclosures that rely on ventilation for protection against accumulation of ignitable mixtures as per 6.1.4 shall be purged with a minimum of five air changes prior to the energization of any devices that are not suitable for the area classification.

All equipment, which shall be energized prior to purging or in order to accomplish purging, shall be suitable for the area classification. Purging need not to be performed if it can be demonstrated by design that the atmosphere within the hydrogen generator enclosure and associated ducts is non-hazardous prior to energization of non-classified electrical equipment.

6.1.8 Ventilation of adjacent compartments

Where ventilated electrical and mechanical compartments are adjacent to the gas generation compartment, they shall be at a positive pressure relative to the gas generation compartment unless equipment within that compartment is suitable for the area classification.

6.1.9 Hydrogen gas detection system

Hydrogen gas detectors used for safety shall comply with 7.7 and IEC 60079-29-1. The manufacturer shall ensure that the selection, installation, use and maintenance of hydrogen gas detectors are in accordance with IEC 60079-29-2. The detectors shall be installed in optimum locations to provide the earliest detection of hydrogen gas such that their protective function can be proven.

The reliability of a hydrogen gas detection system used for safety purposes shall comply with the requirements of 6.2.4.

Self-verification means shall be provided for hydrogen gas detectors used for safety purposes.

Hydrogen gas detection systems used for safety shall comply with the requirements of Clause 7 and especially 7.1 and 7.2.4.

NOTE This requirement does not apply to hydrogen gas detectors or detection systems provided for other non-safety purposes such as diagnostics.

6.1.10 Hydrogen generators designed to be installed in classified areas

Hydrogen generators that are designed to be installed in classified areas as defined by IEC 60079-10 shall have their electrical equipment complying with IEC 60079-0 and the appropriate parts of IEC 60079 for the type(s) of protection used. In this case, the provisions of 6.1.4 shall not be used.

Table 1 — Electrical components requirements

Type of electrical equipment — Main category	Type of electrical equipment — Specific equipment	International Standards
Circuit-breakers		IEC 60947-2
Switches, disconnectors, switch-disconnectors and fuse-combination units		IEC 60947-3
Contactors and motor-starters	Electrotechnical contactors and motor-starters	IEC 60947-4-1
	AC semiconductor motor controllers and starters	IEC 60947-4-2
	AC semiconductor controllers and contactors for non-motor loads	IEC 60947-4-3
Control circuit devices and switching elements	Electromechanical control circuit devices	IEC 60947-5-1
	Proximity switches	IEC 60947-5-2
	Proximity devices with defined behaviour under fault conditions	IEC 60947-5-3
	Electrical emergency stop device with mechanical latching function	IEC 60947-5-5
Multiple function equipment	Automatic transfer switching equipment	IEC 60947-6-1
	Control and protective switching devices for equipment (CPS)	IEC 60947-6-2
Ancillary equipment	Terminal blocks for copper conductors	IEC 60947-7-1
	Protective conductor terminal blocks for copper conductors	IEC 60947-7-2
Low voltage switchgear and controlgear assemblies	Type-tested and partially type-tested assemblies	IEC 60439-1
	Busbar trunking systems (busways)	IEC 60439-2
	Low-voltage switchgear and controlgear assemblies intended to be installed in places where unskilled persons have access for their use – Distribution boards	IEC 60439-3
	Assemblies intended to be installed outdoors in public places – Cable distribution cabinets (CDCs) for power distribution in networks	IEC 60439-5
Semiconductor converters		IEC 60146 (all parts)
Rotating electric machines (motors)		IEC 60034-1
Power supplies		IEC 61204 and IEC 61204-6
Switch mode power supplies		IEC 61558-2-17
Power transformers, including: separating transformers, control transformers, isolating transformers, constant voltage transformers, and autotransformers		IEC 61558 (all applicable parts)
Semiconductor devices		IEC 60747 (all applicable parts)

6.2 Electrical equipment

6.2.1 General requirements

Electrical safety shall ensure protection against electrical shock, fire and burns during operation and routine maintenance activities.

Electrical clearance (through air) and creepage distances (over surfaces) as well as solid insulation thickness for electrical circuits, shall be in accordance with Clause 20 of IEC 60730-1:1999/Amd.1: 2003/Amd. 2:2007.

Wiring methods shall comply with the requirements of IEC 60204-1.

Electrical installation and service connection leads or terminals of an individual component shall be identified by number(s), letter(s), symbol(s) or combination thereof, except when the component:

a) incorporates means which will physically prevent incorrect wiring, or

b) incorporates only two leads or terminals, the interchange of which does not change the operation of the component.

Wire for power circuits shall be colour coded to allow for consistent identification. Conductors shall be identified as per IEC 60446.

Equipment terminals shall be identified as per IEC 60445.

Electrical components and devices shall be:

— suitable for their intended use and shall conform to relevant IEC International Standards indicated in Table 1;

— installed and used within their ratings and as per the manufacturer's instructions.

6.2.2 Grounding and bonding

Equipment shall be bonded and grounded as required by IEC 60204-1 with the following exception:

Parts that shall be isolated from the ground to ensure safe and reliable operation of the process by limiting stray currents such as electrolytic cell metal casings and parts, other electrolyte carrying vessels and cell ancillary systems such as feed water and cooling systems shall be protected as required under IEC 60204-1 to prevent electric shock.

6.2.3 Circuit protection

Overload and over current protection shall be provided to each electrical device, equipment and apparatus by means of circuit breakers, overload relays and fuses in accordance with one of the following IEC International Standards.

a) IEC 60364-4-43;

b) IEC/TR 61459.

6.2.4 Safety control circuit

A risk assessment shall be performed in accordance with ISO 14121-1 to identify the critical functional components of the hydrogen generator.

NOTE IEC 60300-3-9 also provides recommended guidelines for risk assessment.

All the electrical components that have been identified as critical functional components based on the results of the risk assessment shall be provided with a safety control circuit. The design of the safety control circuits shall be in accordance with IEC 61069-7 and IEC 61511-1.

The design of safety-control circuits shall be such that failure of critical functional components will cause the hydrogen generator to go to a safe condition, as follows:

a) the component shall act to safely interrupt the intended function under its control, or

b) the component shall allow to complete an operational cycle, but shall fail to start or will lock out on the subsequent cycle.

The safety control circuits shall ensure that the interchange of the electrical installation and service connection leads or terminals of the critical functional component that failed, when physically interchangeable without alteration, shall not activate the component nor result in normal operation of the component.

7 Control systems

7.1 General

The hydrogen generator shall be equipped with a control system that is designed and constructed so that the hydrogen generator is safe and reliable and will prevent a dangerous condition from occurring.

The manufacturer shall perform a safety analysis to identify failures that can affect the system performance and/or safety. The safety analysis shall provide the basis to set the protection parameters required for the functionality of the safety control circuits described in 6.2.4. The response time and accuracy of the instruments used for the detection and the actuation of a control shall be accounted for in the safety analysis.

The hydrogen generator shall be designed such that the single failure of a safety control circuit component shall not cascade into a hazardous situation. As indicated in IEC 60204-1, means to prevent cascade failure include but are not limited to:

— protective devices in the machine (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.

The control system shall incorporate safety devices and, where appropriate, monitoring devices such as indicators and/or alarms which enable and provide information for appropriate action to be taken, either automatically or manually, to keep the hydrogen generator operating within allowable limits.

If the manufacturer's safety analysis determines that hydrogen in air, hydrogen in oxygen or oxygen in hydrogen combustible gas mixture hazards require an emergency stop function, then the emergency stop shall be initiated when the maximum volume fraction of 1 % hydrogen in air, 2 % hydrogen in oxygen or 1,6 % oxygen in hydrogen, is exceeded. The response time and accuracy of the instruments used for detection and actuation of a control shall be accounted for in the safety analysis.

Each operational mode of the hydrogen generator shall be indicated.

7.2 Operator Controls

7.2.1 Start

The hydrogen generator shall have a start control that initiates operation of the hydrogen generator only when all safeguards are in place and functional.

7.2.2 Stop

The hydrogen generator shall have a stop control that initiates a safe controlled cessation of hydrogen generator operation.

7.2.3 Reset

The hydrogen generator may have a reset control to reset controls and safeguards to a safe state ready for start after an automatic shut down event due to fault detection.

7.2.4 Emergency stop

The hydrogen generator shall have an emergency stop function that immediately removes power from systems that produce an actual or impending hazard that cannot be corrected by controls.

The emergency stop shall meet the requirements of IEC 60204-1 and ISO 13850.

7.2.5 Suspension of safeguards

Where it is necessary to suspend safeguarding (e.g. for maintenance by qualified service personnel), a mode selection device or means, capable of being secured by a special tool or code in the desired mode, shall be provided so as to prevent unintended operation.

7.3 Control function in the event of failure

In case of a fault in the control circuit, a failure or a damage to the control circuit:

a) the hydrogen generator shall not start unexpectedly;

b) the hydrogen generator shall not be prevented from stopping if the stop command has been given;

c) automatic or manual stopping of the moving parts shall be possible;

d) the protective safety devices shall remain fully effective.

7.4 Programmable electronic equipment

Programmable electronic equipment shall not be used for emergency stop (category 0) functions. Programmable electronic equipment for monitoring, testing and non-safety critical functions shall meet the requirements of IEC 60204-1 and shall comply with IEC 61131-1 and IEC 61131-2.

Programmable controllers used for safety control circuits shall comply with IEC 61508-1, IEC 61508-2 and IEC 61508-3.

7.5 Correctable conditions

The hydrogen generator may continue to operate from out-of-specification conditions that can be corrected by reducing power levels or changing other operating parameters to prevent a hazardous situation.

7.6 Interconnected installations

When the hydrogen generator is designed to work together with other equipment, the hydrogen generator shall provide effective means to communicate safety related conditions between the hydrogen generator and other equipment.

7.7 Safety components

Safety components shall incorporate appropriate safety factors as prescribed by the manufacturer's safety analysis to ensure that the alarm threshold lies outside the limits to be registered, taking into account, in particular, the operating conditions of the installation and possible faults in the measuring system.

Safety components shall:

— be so designed and constructed as to be reliable and suitable for their intended use;

— be independent of other functions, unless their safety functions cannot be affected by such other functions;

— comply with design principles in order to obtain suitable and reliable protection. These principles include, in particular, fail-safe modes, redundancy, diversity and self-diagnosis.

7.8 Remote control systems

Remote monitoring and control systems shall:

a) be allowed only on hydrogen generators where remote start-up will not lead to an unsafe condition;

b) not override locally set manual controls;

c) not override protective safety controls.

Hydrogen generators that can be operated remotely shall have a local, labelled switch or other device that will prevent remote operation when a local operator performs inspection or maintenance.

7.9 Alarms

When a condition that affects the safe operation of the hydrogen generator occurs, an alarm signal shall be sent to an operator, or a local or remote control centre. The signal shall describe the condition so that an operator can take an action to correct this unsafe condition.

8 Ion transport medium

8.1 Electrolyte

The electrolyte, whether liquid or solid, shall:

a) be chemically stable with respect to environmental degradation over the full range of operating conditions and over the defined operating lifetime of the hydrogen generator or any of its subcomponents;

b) not introduce any undesirable attribute in any other material used in conjunction so as to have a synergistic and undesirable effect that neither material would possess if used in isolation;

c) not catalyze or serve to promote in any fashion parasitic side reactions, either of a chemical or an electrochemical form, that contaminate the product gases of hydrogen or oxygen;

d) be selected from the aqueous bases and solid polymeric materials with acidic function group additions;

e) provide sufficient ionic conductivity to prevent degradation of the oxygen/hydrogen separator (membrane).

The manufacturer shall provide a mechanism for the safe containment and environmental disposal of the electrolyte upon either a planned released or unplanned event leading to the release of the electrolyte.

8.2 Membrane

The hydrogen generator shall be provided with a membrane to separate the product gas streams of oxygen and hydrogen. The membrane shall:

a) be chemically stable with respect to environmental degradation over the full range of operating conditions;

b) be selected from the group of natural fibres, synthetic polymers and/or ceramics and shall not contain asbestos;

c) provide sufficient ionic conductivity for the safe operation of the hydrogen generator;

d) provide sufficient electrical resistivity for the safe operation of the hydrogen generator.

The manufacturer shall provide a mechanism for the safe environmental disposal of the membrane upon hydrogen generator disassembly and replacement. If there is a possibility that the membrane material could become unstable over the defined operating lifetime of the hydrogen generator, the manufacturer shall:

a) ensure that the material instability will not affect the safety of the hydrogen generator;

b) incorporate monitoring devices that will monitor the effects of the membrane material instability.

9 Protection of service personnel

The exterior and interior of the hydrogen generator enclosure and the interior components shall be designed with due consideration to ISO 13852, ISO 13853 and ISO 13854.

All live parts and/or moving parts such as flywheels shall be protected from access by unauthorized personnel. Entrances to exposed live parts inside the hydrogen generator shall have warning signs prohibiting access by unqualified personnel.

Guarding shall be provided to protect the service personnel from any contact shock of exposed live parts as well as from any rotating device.

A non-insulated live part in a high-tension circuit within the hydrogen generator compartments shall be located, guarded or enclosed so as to minimize the possibility of accidental contact by service personnel performing mechanical service functions which may have to be performed with the equipment energized.

An electrical control component that may require examination, adjustment, servicing or maintenance while energized shall be located and mounted with respect to other components and grounded metal parts so it is accessible for electrical service functions without subjecting the service personnel to the likelihood of shock hazard from adjacent non-insulated live parts or accident hazard from adjacent moving parts.

10 Test methods

10.1 Type (Qualification) tests

10.1.1 General requirements

Each new hydrogen generator design considered for compliance with this International Standard shall be subjected to the type (qualification) tests of 10.1 to verify that the design specification is fulfilled.

A hydrogen generator design tested for compliance with this International Standard shall be a representative production sample.

10.1.2 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 in accordance with the manufacturer's instructions to replicate the manner in which it is to be installed and operated.

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

a) at the maximum normal operating pressure;

b) at the rated voltage, and frequency.

Tests shall be carried out on the hydrogen generator assembled for normal use and under least favourable combination and configuration, within the manufacturer's stated ratings.

10.1.3 Reference test conditions

10.1.3.1 Environmental conditions

Unless otherwise specified in this International Standard, the tests shall be carried out in the following environment:

a) a temperature of 15 °C to 35 °C;

b) a relative humidity within the limits specified by the manufacturer (see 4.3) without exceeding 75 %;

c) an atmospheric pressure of 75 kPa to 106 kPa;

d) no hoarfrost, dew, percolating water, rain, solar radiation, etc.

10.1.3.2 State of equipment

10.1.3.2.1 General

Unless otherwise specified, each test shall be carried out on the equipment assembled for normal use and under the least favourable combination of the conditions given in 10.1.3.2 to 10.1.3.2.13.

If dimensions or mass make it unsuitable to carry out particular tests on a complete hydrogen generator, tests on sub-assemblies may be carried out, provided the assembled hydrogen generator meets the requirements of this International Standard.

Equipment intended to be built into a wall, recess, cabinet, etc., shall be installed as specified in the manufacturer's instructions.

10.1.3.2.2 Position of the hydrogen generator

The hydrogen generator shall be in any position of normal use and with any ventilation unimpeded.

10.1.3.2.3 Accessories

Accessories and operator-interchangeable parts available from, or recommended by, the manufacturer for use with the hydrogen generator under test may either be connected or not connected.

10.1.3.2.4 Covers and removable parts

Covers or parts that can be removed without using a tool may either be left in place or removed.

10.1.3.2.5 Mains supply voltage

The mains supply voltage shall be between 90 % and 110 % of any rated supply voltage specified by the manufacturer. If the hydrogen generator is rated for a fluctuation greater than between 90 % and 110 % of the rated supply voltage, the mains supply voltage can be at any supply voltage within the fluctuation range specified by the manufacturer.

The frequency shall be any rated frequency.

Hydrogen generators designed for both alternative current (a.c.) and direct current (d.c.) shall be connected to either an a.c. or d.c. supply.

Hydrogen generators designed for d.c. or single-phase supply shall be connected both with normal and reverse polarity.

Unless the hydrogen generator is specified for use only on a non-earthed mains supply, one pole of the reference test supply shall be at or near earth potential.

If the means of connection permits reversal, battery-operated hydrogen generators shall be connected with both reverse and normal polarity.

10.1.3.2.6 Input and output voltages

Input and output voltages, including floating voltages but excluding the mains supply voltage, shall be set to any voltage within the rated voltage range.

10.1.3.2.7 Earth terminals

Protective conductor terminals, if any, shall be connected to earth. Functional earth terminals may be connected or not connected to earth.

10.1.3.2.8 Controls

Controls that can be adjusted by hand by an operator shall be set to any position except that:

a) mains selection devices shall be set to the value of the mains supply actually used;

b) combinations of settings shall not be made if they are prohibited by the manufacturer's marking on the equipment.

10.1.3.2.9 Connections

The hydrogen generator may be connected to the application equipment for which it is intended.

10.1.3.2.10 Load on motors

Load conditions of motor-driven parts of the hydrogen generator shall be in accordance with the intended purpose.

10.1.3.2.11 Output

The following shall be taken into account regarding the hydrogen generator equipment giving an electrical output:

a) the equipment shall be operated in such a way as to provide the rated output power to the rated load;

b) the rated load impedance of any output may be connected or not connected.

10.1.3.2.12 Duty cycle

Equipment for short-term or intermittent operation shall be operated for the longest period and shall have the shortest recovery period consistent with the manufacturer's instructions.

Equipment for short-term or intermittent operation that develops significant heat during the start-up phase, and that relies on continued operation to dissipate that heat, shall also be operated for the shortest rated period followed by the shortest rated recovery period.

10.1.3.2.13 Loading and filling

Equipment intended to be loaded with a specific material in normal use shall be loaded with the least favourable quantity of the materials specified in the instructions for use, including not loaded (empty) if the instructions for use permit this in normal use.

In case of doubt, tests should be performed in more than one loading condition.

If the specified material could cause a hazard during the test, another material may be used provided that it can be demonstrated that the result of the test is not affected.

10.1.4 Electrical tests

10.1.4.1 Continuity of the protective bonding circuit test

The continuity of the protective bonding circuit specified in 6.2.2 shall be verified by a loop impedance test in accordance with 61.3.6.3 of IEC 60364-6:2006.

An alternative test method may be used for hydrogen generators with protective bonding loops not exceeding 30 m. In this case, the continuity of the protective bonding circuit may be verified by the following bonding impedance tests:

— 6.5.1.3 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 for plug-connected equipment;

— 6.5.1.4 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 for permanently connected equipment.

Another alternative test method may be used when and only when test equipment with current generating capacity required by the test of IEC 61010-1 is not readily available. In this case, the continuity of the protective bonding circuit shall be verified by the test of 8.2 of IEC 60204-1:2005.

NOTE The continuity of the protective bonding circuit should be verified before power is applied to the hydrogen generator as most short circuit protective devices rely on this continuity for proper operation. Similarly, the continuity of the protective bonding circuit should be verified before the voltage test of 10.1.4.2.

10.1.4.2 Voltage test

The strength of the electrical insulation specified in 6.2.1 shall be verified in accordance with 6.8 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 with the following exceptions:

- humidity preconditioning shall not be required for hydrogen generators too large for readily available test chambers. The voltage testing requirements for such large hydrogen generators shall in no case be less than those of 18.4 of IEC 60204-1:2005.
- any of the tests of 6.8.4 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 may be used.

NOTE 1 If the hydrogen generator employs a component such as a solid-state device that can be damaged by the voltages specified in this test, and that component complies with the applicable International Standard specified in 6.2.1, the conductors of the circuit being tested may be disconnected at the component to eliminate the likelihood of damaging the component.

NOTE 2 The voltage test should be performed after the continuity of the protective bonding circuit is verified to minimize the possibility of inadvertently energizing accessible conductive surfaces and to ensure proper operation of the test equipment.

NOTE 3 The strength of the electrical insulation should be verified before applying power to the hydrogen generator to minimize the potential for short circuits and exposure to hazardous voltages.

10.1.4.3 Functional tests

The functions of electrical equipment shall be tested, particularly those related to safety and safeguarding. As a minimum, the functioning of the safety control circuit and components identified in 6.2.4 and the control system of Clause 7 shall be verified with the requirements of 5.3.7, 6.2.4, 7.1, 7.2, 7.3, 7.6, 7.7 and 7.9.

The following faults and conditions shall be considered in the analysis and testing for 6.2.4:

- cell stack voltage under/over the maximum/minimum voltage specified by the manufacturer;
- cell stack unbalanced voltage as specified by the manufacturer;
- cell stack temperature higher than the maximum temperature specified by the manufacturer;
- cell stack current over the maximum current specified by the manufacturer;
- electrolyte level higher than the maximum level specified by the manufacturer;
- electrolyte level lower than the minimum level specified by the manufacturer;
- volume fraction of hydrogen in air that exceeds the limits defined in 6.1.4, or 7.1;
- volume fraction of hydrogen in oxygen that exceeds the limits defined in 7.1;
- volume fraction of oxygen in hydrogen that exceeds the limits defined in 7.1;
- hydrogen pressure higher than the maximum pressure specified by the manufacturer;
- loss of ventilation in the hydrogen generator enclosure;
- temperature lower than the minimum temperature specified by the manufacturer;
- temperature higher than the maximum temperature specified by the manufacturer;
- hazardous liquid leak;

- rupture disk failure;
- shutoff valve failure.

NOTE The functional tests and especially those of the safety circuit should be performed immediately after the continuity of the protective bonding circuit and the strength of the electrical insulation have been verified and before the hydrogen generated is operated at full capacity.

10.1.4.4 Mains supply

The mains supply marking shall be checked in accordance with 5.1.3 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003.

10.1.4.5 Touch current and protective conductor current

The touch current and protective conductor current shall be limited and tested in accordance with Clause 5.1 of IEC 60950-1:2005/Cor. 1:2006.

10.1.5 Pressure tests

10.1.5.1 General

All pressures cited in 10.1.5 are gauge unless stated otherwise.

10.1.5.2 Pressure test — Liquid containing parts

The strength and integrity of all pressure bearing parts of 5.4, including joints and connections, that convey a liquid shall be tested by the methods of 11.7 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003.

NOTE 1 Cell stacks need only be tested to 10.1.5.4.

NOTE 2 Parts subjected to the same internal pressure during normal operation of the hydrogen generator through (inter) connection may be considered as an individual test section, which may be pressurized separately and, when deemed necessary, isolated from the rest of the hydrogen generator by any convenient means.

10.1.5.3 Pressure test — Gas containing parts

The strength and integrity of all pressure bearing parts of 5.4, including joints and connections, that convey a gas shall be tested by the methods of 11.7 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 with the following modifications:

a) test pressure shall be at least 1,5 times their maximum design pressure;

b) the minimum test pressure shall be 70 kPa;

c) the test duration shall be 2 min ± 10 s.

NOTE 1 Cell stacks need only be tested to 10.1.5.4.

NOTE 2 In addition to verifying the ability of the pressure bearing parts to withstand pressure, this test confirms the integrity of the hydrogen containment system including piping, fittings, and vessels in support of the fire and explosion hazard protection requirements of 6.1. See 16.6 of IEC 60079-2:2007.

Parts subject to the same internal pressure during normal operation of the hydrogen generator through (inter) connection may be considered as an individual test section, which may be pressurized separately and, when deemed necessary, isolated from the rest of the hydrogen generator by any convenient means.

If a pneumatic test is used, clean dry air or any non-reactive gas, such as nitrogen or helium, should be used.

10.1.5.4 Pressure test — Cell stacks

10.1.5.4.1 Applicability

The cell stacks shall be subjected to the common pressure test of 10.1.5.4.2. If during normal or abnormal operation, a pressure difference between the oxygen and hydrogen sides of the cell stacks can occur, the maximum design pressure difference shall be specified by the manufacturer and the cell stack shall additionally be subjected to the differential pressure test of 10.1.5.4.3.

NOTE 1 A slightly different test is provided for cell stacks because unlike the other pressure bearing components the cell stacks are the pressure source. If the cell stacks fail, the source of both pressure and hydrogen is removed.

NOTE 2 Robust cell stacks can be tested with the other pressure equipment as described in 10.1.5.2 and 10.1.5.3.

10.1.5.4.2 Common pressure test

The oxygen and hydrogen sides of each cell stack shall be connected to a common pressure source and tested simultaneously. The pressure test shall be performed as per 10.1.5.3 except that the cell stacks with a maximum design pressure of less than or equal to 50 kPa shall be subjected to 1,3 times their maximum design pressure for 30 min.

10.1.5.4.3 Differential pressure test

The cell stacks shall be heated or cooled to the maximum or minimum normal operating temperature, whichever is more severe. The pressure test shall be performed as per 10.1.5.3 except that the pressure shall be applied to either the anode or cathode channels but not both and the test pressure shall be 1,3 times the maximum design differential operating pressure.

Additionally, the leakage rate between anode and cathode sides shall be measured either continuously during the test, or before and after pressurization. The leakage rate between anode and cathode side shall not increase as a result of this test and shall be within the manufacturer’s specification for the temperature of the test. The measurements after pressurization shall not deviate from the initial results by more than the accuracy and repeatability of both the instrumentation and the test set-up.

10.1.5.5 Leakage test

The leakage test shall be performed to supplement the pressure tests of 10.1.5 especially in cases where parts of the hydrogen generator have been tested separately and then connected together. Any functional parts shall be in the open position so the required test pressure is exerted on all parts of the test section.

The tests of 10.1.5.2 through 10.1.5.4 shall be repeated on the fully assembled hydrogen generator with the following modifications:

— The test pressure shall be of no less than the maximum normal operating pressure;

— When the test pressure is reached, the flow of test fluid shall be stopped and the pressure in the hydrogen generator shall be monitored for 2 min. There shall be no measurable pressure drop.

NOTE Temperature compensation shall be taken into account when determining any pressure losses.

10.1.6 Dilution tests

Where ventilation is used to dilute hydrogen and/or oxygen as described in 6.1.4 and 6.1.5, the tests of 10.1.6.1 to 10.1.6.3 shall be performed.

The air pressure and airflow measured during the test conditions shall be corrected for temperature and altitude. The corrected airflow and pressure shall meet the design criteria for the specified operating range of the hydrogen generator.

NOTE For the dilution tests to be valid, the integrity of the containment system should have been confirmed by the tests of 10.1.5.3 and 10.1.5.4.

10.1.6.1 Air flow test

The air flow rate shall be measured to confirm that the flow rate meets or exceeds the ventilation rate specified in 6.1.6. The ventilation rate shall be determined by measuring air flow into or out of the hydrogen generator enclosure.

10.1.6.2 Air pressure test

The pressure of the ventilated area shall be measured to confirm that the pressure differential meets the requirements specified in 6.1.6.

10.1.6.3 Dilution test

The effectiveness of the dilution by ventilation specified in 6.1.4, 6.1.5 and 6.1.6 shall be confirmed using the method of 16.4.4.2 of IEC 60079-2:2007.

10.1.7 Protection against the spread of fire tests

Protection against the spread of fire shall be tested by the methods of Clause 9 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003.

NOTE The International Standards for fire resistance referenced in 5.3.3 contain additional tests.

10.1.8 Temperature tests

Protection against burns and the overheating of components shall be tested by the methods of Clause 10 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003.

10.1.9 Environmental tests

10.1.9.1 Ingress protection

The electrical enclosure and process enclosures of a hydrogen generator shall be tested by the methods of IEC 60529 for compliance with the IP classification determined per 5.3.2.

NOTE In addition to providing protection from the environment, enclosures may prevent access to hazardous live electrical parts as required by 6.2.1. See 6.2 of IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003 for more information and a preferred means of testing for this particular protection.

10.1.9.2 Water test

The electrical enclosure and process enclosures of hydrogen generators intended for outdoor use shall be tested by the methods of 6.3 of IEC 60068-2-18:2000 or by the methods of IEC 60529 to IPX5.

NOTE Components and equipment individually protected to levels required by this International Standard (or better) do not need to be enclosed.

10.1.10 Performance tests

10.1.10.1 Hydrogen and oxygen production rate test

The hydrogen and, if applicable, the oxygen production rate shall be measured at 100 % capacity for a period of 1 h using the method defined in ISO 9300, ISO 9951, ISO 10790 or ISO 14511.

The average production rate shall meet or exceed the rate specified by the manufacturer.

10.1.10.2 Hydrogen and oxygen quality test

The applicable hydrogen quality parameters shall be verified as per ISO 14687.

If applicable, the oxygen quality parameters shall be verified as per the manufacturer's instructions.

10.2 Routine tests

10.2.1 General requirements

Routine tests shall be performed on every hydrogen generator.

10.2.2 Continuity of the protective bonding circuit test

The continuity of the protective bonding circuit shall be tested as specified in 10.1.4.1 of this part of ISO 22734 or IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003, Clause F.1.

NOTE Any of the alternative methods listed in 10.1.4.1 may be used regardless of the size or ratings of the hydrogen generator.

10.2.3 Voltage test

The electrical insulation shall be tested as specified in 10.1.4.2 of this part of ISO 22734 or IEC 61010-1:2001/Cor. 1:2002/Cor. 2:2003, Clauses F.2 and F.3.

10.2.4 Functional tests

The functions of each hydrogen generator shall be tested as specified in 10.1.4.3

10.2.5 Leakage test

The integrity of each hydrogen generator's piping shall be tested as specified in 10.1.5.5.

11 Marking and labelling

11.1 General requirements

The hydrogen generator shall be marked in compliance with the applicable clauses of ISO 3864-2 and ISO 17398.

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

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

b) catalogue number and the model number or type;

c) date of construction;

d) electrical input range in volts;

e) current rating in amperes or the rated power (watts or VA);

f) frequency in hertz and phases;

g) serial number of the hydrogen generator;

h) IP rating for outdoor or indoor use as determined in 5.3.2;

i) capacity of generation of hydrogen in cubic meters per hour at a temperature of 273,15 K (0 °C) and an atmospheric pressure of 101,325 kPa;

j) hydrogen output pressure range in kilopascals;

k) temperature range of output hydrogen in degrees Celsius (°C);

l) if applicable, the area classification rating;

m) if applicable, the capacity of generation of oxygen in cubic meters per hour at a temperature of 273,15 K (0 °C) and an atmospheric pressure of 101,325 kPa;

n) if applicable, the oxygen output pressure range in kilopascals;

o) if applicable, the temperature range of output oxygen in degrees Celsius (°C);

p) reference to this International Standard.

11.3 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.

11.4 Warning signs

Warning signs shall be placed to identify vented hydrogen and oxygen, electrical hazards, contents from drain valves, hot components and mechanical hazards. Warning signs shall conform to ISO 3864.

11.5 Additional requirements for hydrogen generators containing classified areas and for hydrogen generators designed to be used in classified areas

Hydrogen generators containing classified areas as determined in 6.1.2 and hydrogen generators designed to be used in classified areas (see 6.1.10) shall be marked as required by IEC 60079-0 and the appropriate parts of IEC 60079 for the type(s) of protection used.

11.6 Additional requirements for oxygen venting

If required by 4.5, a label warning of enriched oxygen shall be affixed near the oxygen outlet.

12 Documentation accompanying the hydrogen generator

12.1 Instructions and diagrams contained in the hydrogen generator

Where this International Standard requires instructions and diagrams to be contained in the hydrogen generator, they shall be contained within the hydrogen generator enclosure, either in a protective pouch or displayed using a permanent marking method resistant to water and heat.

12.2 Handling and lifting instructions

Instructions on how to safely handle and lift the hydrogen generator shall be provided by the manufacturer.

The hydrogen generator shall have its centre of gravity identified. Lifting point to facilitate lifting by crane, forklift or other means as may be appropriate for the size and weight of the hydrogen generator shall be provided and identified.

12.3 Operation manual

Operation instructions including start-up and shutdown procedures shall be provided by the manufacturer.

The operation manual shall include a Clause on the hazards related to the use of the hydrogen generator. As a minimum, the hazards related to the presence of hydrogen and oxygen, the hazards related to the handling of the electrolyte and the hazards related to the use of purge gases shall be covered.

The operation manual shall also include a description and explanation of all warnings and markings on the hydrogen generator especially those relating to classified areas.

The operating manual shall explain the hazards of oxygen enriched atmosphere and describe the minimum room ventilation required to maintain oxygen levels below a volume fraction of 23,5 % in air.

If the hydrogen generator is provided with a remote monitoring system and adjustments to its controls can be made by the customer or operator, the manufacturer shall supply the procedures to address the changes to this remote monitoring system. The procedures shall address the cases 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 how to:

a) modify the control parameters remotely;

b) certify an upgrade to the remote monitoring system;

c) upgrade software remotely;

d) certify a parameter change;

e) change parameters remotely;

f) upload parameters;

g) upload software;

h) qualify the operation;

i) undo/reverse all changes;

j) test and backup documentation.

12.4 Electrical diagrams

Electrical diagrams of all electrical circuits within the hydrogen generator shall be supplied by the manufacturer in each of the following forms:

a) connection diagram(s) to aid in locating components for field service;

b) schematic diagram of the ladder form and, when necessary for clarification, a cycle chart or printed sequence of switching action accompanying the schematic diagram.

Electrical diagrams shall be affixed on the hydrogen generator in a location where they are accessible during servicing of the electrical components and/or included with the instructions per 12.3. In all cases, the colour-coding scheme shall be posted in a prominent location within the hydrogen generator enclosure and provided in the operation manual.

12.5 Installation instructions

The manufacturer shall provide installation instructions. These instructions shall provide a section entitled "Hydrogen Generator Site Layout and Design," which provides guidelines on: unpacking, location and design of the hydrogen generator foundation; ventilation requirements; protection from weather hazards; recommended height in relation to the base flood elevation; security enclosure; acceptable distances from vegetation, sidewalks, public ways, roads, and railroad tracks; and protection from vehicular impact.

The installation instructions shall define the required feed water, power, venting, and other services and utilities required for operation of the hydrogen generator.

The installation instructions shall also include specific instructions for the proper installation of the hydrogen generators that are designed to be installed in classified areas in order to ensure compliance with IEC 60079-0 and with any other parts of IEC 60079 used for protection. For hydrogen generators using ventilation as an active means to protect against the accumulation of ignitable mixtures (see 6.1.4 and 6.1.7), the installation instructions shall also include requirements for:

— source of purge gas including area classification if air is used as the purge gas;

— exhaust of purge gas including area classification if air is used as the purge gas;

— ducting;

— room ventilation (if air).

If applicable, the installation instructions shall indicate the classification and extent of any classified areas surrounding the hydrogen generator.

If oxygen is to be vented indoors, the installation instructions shall explain the hazards of oxygen enriched atmosphere and describe the minimum room ventilation required to maintain oxygen levels below a volume fraction of 23,5 % in air. Criteria shall be provided to determine when oxygen shall be vented outdoors. Instructions for the method of ventilation shall be provided.

The installation instructions shall provide guidelines for the proper venting of hydrogen and, if applicable, oxygen and the proper installation of the vent lines. The installation instructions shall indicate that relieved gases that are vented outdoors shall be vented to a safe area and that relieved gases vented within the hydrogen generator enclosure or indoors shall be vented into a classified area. The installation instructions shall also indicate such issues that should be specifically resolved with state, provincial and local regulatory authorities based on adopted building construction regulations and zoning ordinances.

The seismic zone rating, if necessary, shall also be included in the installation instructions.

12.6 Maintenance instructions

Each hydrogen generator shall be accompanied by separate instructions to be referred to as the maintenance manual. This manual shall contain clearly defined, legible and complete instructions for at least the following:

a) instructions for starting, shutting down and servicing the hydrogen generator. These instructions shall pictorially illustrate and locate all components;

b) recommendations for disassembly and transport;

c) where applicable, to avoid risks to health or safety, instructions for the decommissioning and disposal of the hydrogen generator, its materials, and components;

d) instructions for air ventilation including area classification according to IEC 60079-10 or purging required to assure safety during maintenance.

The maintenance manual shall provide an enumeration of all regular and routine maintenance to be performed on the hydrogen generator components and indicate the necessity and minimum frequency for these examinations including:

a) 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;

b) recommended methods for periodic cleaning of necessary parts;

c) instructions for lubrication of moving parts, including type, grade and amount of lubricant;

d) instructions for the periodic examination of the venting system and all functional parts;

e) information on use and maintenance of apparatus used for the detection and measurement of flammable gases that complies with IEC 60079-29-2;

f) instructions for examining the hydrogen generator installation to ensure that:

   1) any intake or exhaust openings are clear and free of obstructions and that the manufacturer specified clearances are respected;

   2) there are no obvious signs of physical deterioration of the hydrogen generator or its support (i.e., base, frame, cabinet, etc.);

   3) the area surrounding the hydrogen generator is kept clear and free of combustible materials;

   4) the hydrogen generator, or any portion thereof, when located indoors in an insulated space, is kept clear and free of insulating material, with instructions to examine the area when the power supply is installed or when insulation is added and advising that insulating materials may be combustible;

   5) feed water, power, venting, and other services and utilities required for operation of the hydrogen generator are at specification per installation instructions;

g) a list of replacement parts and the source where such parts are available.

The maintenance manual shall specify the periodic inspection of the hydrogen generator that shall be performed by qualified service personnel.

The maintenance instructions shall also include specific instructions for the proper maintenance of the hydrogen generator designed to be installed in classified areas to ensure compliance with IEC 60079-0 and with any other parts of IEC 60079 used for protection.

Annex A
(informative)

Hydrogen assisted corrosion

Users of this International Standard should be aware that engineering materials at high stress and high temperature and exposed to atomic hydrogen in their service environment may exhibit an increased susceptibility to hydrogen assisted corrosion, commonly known as “hydrogen embrittlement.” Hydrogen embrittlement is defined as a process resulting in a decrease of the toughness or ductility of a metal due to the presence of atomic hydrogen.

Hydrogen embrittlement has been recognized classically as being of two types. The first type, known as internal hydrogen embrittlement, occurs when the hydrogen enters the metal matrix through material processing techniques, which supersaturate the metal with hydrogen. The second type, environmental hydrogen embrittlement, results from hydrogen being absorbed by solid metals from the service environment. Thus, 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.

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 subcritical crack growth leading to fracture.

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, microstructure, and mechanical properties;
- 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.

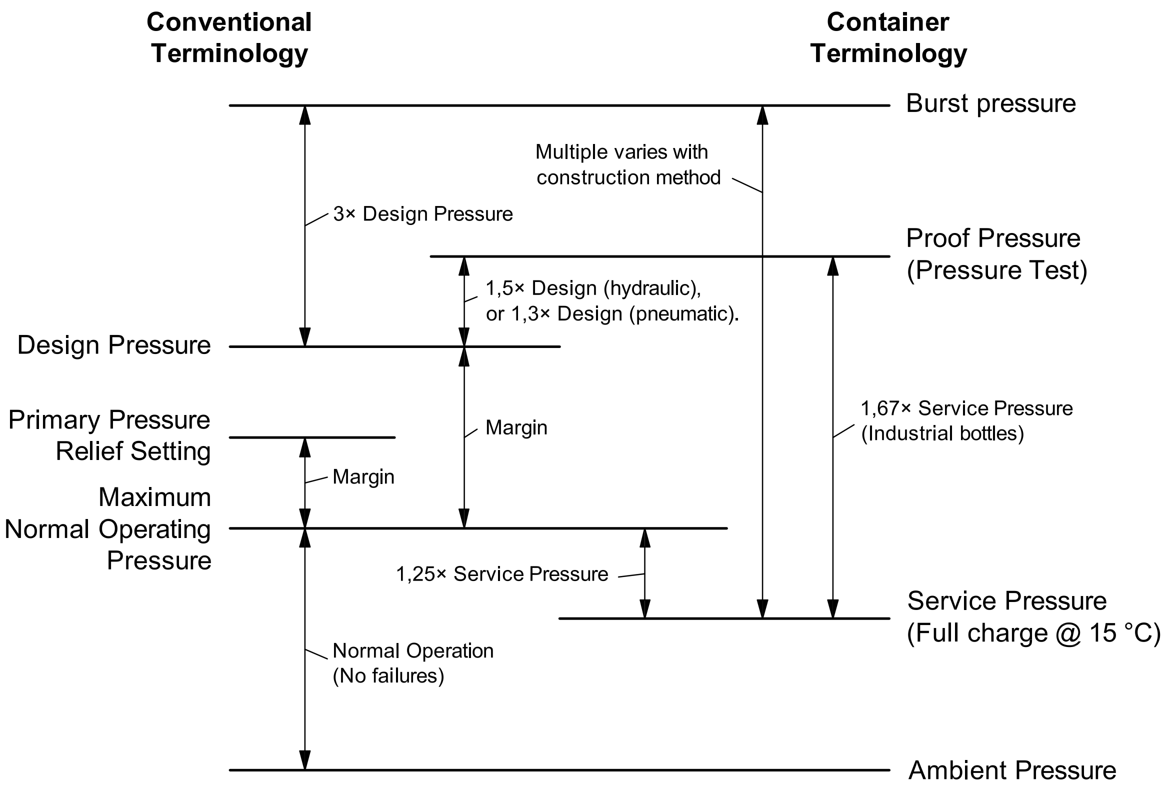
ISO 11114-4 also provides guidance on material resistance to hydrogen embrittlement.

Annex B
(informative)

Conventional Container Terminology

B.1 General

Figure B.1 shows a relative comparison of various pressure terms in conventional container terminology.



NOTE Design pressure is equivalent to former maximum allowable working pressure, MAWP.

Figure B.1

Annex C
(informative)

Flammability limits of hydrogen

C.1 Flammability limit

Flammability limit is defined as vapour concentrations (usually reported as a volume fraction) of fuel (hydrogen) in a flammable mixture that will ignite and propagate a flame.

C.2 Flammability limits of hydrogen

As indicated in Table B.2 of ISO/TR 15916:2004, the flammability limits for hydrogen in air under ambient conditions range from a volume fraction of 4 % to 75 % of hydrogen in air.

These facts combined with changing nomenclature conventions has led to some confusion between standard references to the lower flammability limit (LFL), the lower explosive limit (LEL), and design limits as percentages of these.

To avoid any confusion, flammability limits and corresponding design limits prescribed in this International Standard are expressed only on a volume fraction of hydrogen in air.

Design limits prescribed in this International Standard are conservatively well outside the volume fraction of 4 % to 75 % of hydrogen in air.

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