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Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications

Générateurs d'hydrogène utilisant le procédé de l'électrolyse de l'eau — Applications industrielles, commerciales et résidentielles

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This first edition cancels and replaces ISO 22734-1:2008 and ISO 22734-2:2011, which have been combined and technically revised. The technical revisions add Alkaline Exchange Membranes to the document scope, update Normative references, clarify pressure terminology definitions, and simplify Risk Management requirements. This document is reorganized into 7 clauses, where all design requirements are now found in Clause 4, and all test methods are now found in Clause 5.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In a hydrogen generator electrochemical 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 compared with 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, monitoring equipment and controls are contained within an enclosure. Gas compression, feed water conditioning, and auxiliary equipment may also be included.

This document is intended to be used for certification purposes.

Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications

1 Scope

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

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

— group of aqueous bases;

— group of aqueous acids;

— solid polymeric materials with acidic function group additions, such as acid proton exchange membrane (PEM);

— solid polymeric materials with basic function group additions, such as anion exchange membrane (AEM).

This document is applicable to hydrogen generators intended for industrial and commercial uses, and indoor and outdoor residential use in sheltered areas, such as car-ports, garages, utility rooms and similar areas of a residence.

Hydrogen generators that can also be used to generate electricity, such as reversible fuel cells, are excluded from the scope of this document.

Residential hydrogen generators that also supply oxygen as a product are excluded from the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1182, *Reaction to fire tests for products — Non-combustibility test*

ISO 3746, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Survey method using an enveloping measurement surface over a reflecting plane*

ISO 3864-2, *Graphical symbols — Safety colours and safety signs — Part 2: Design principles for product safety labels*

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 4126-6, *Safety devices for protection against excessive pressure — Part 6: Application, selection and installation of bursting disc safety devices*

ISO 7010, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

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

ISO 9614-1, *Acoustics — Determination of sound power levels of noise sources using sound intensity — Part 1: Measurement at discrete points*

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 10286, *Gas cylinders — Terminology*

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

ISO 11119-1, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 1: Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l*

ISO 11119-2, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners*

ISO 11119-3, *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing — Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

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 function — Principles for design*

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

ISO 13857, *Safety of machinery — Safety distances to prevent hazard zones being reached by upper and lower limbs*

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

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, *Ergonomic 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 16111, *Transportable gas storage devices — Hydrogen absorbed in reversible metal hydride*

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*

ISO 26142, *Hydrogen detection apparatus — Stationary applications*

IEC 31010:2019, *Risk management — Risk assessment techniques*

IEC 60068-2-18:2017, *Environmental testing — Part 2-18: Tests — Test R and guidance: Water*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60335-1:2010, *Household and similar electrical appliances — Safety — Part 1: General requirements*

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

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

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

IEC 60364-4-41, *Low voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock*

IEC 60364-4-43, *Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent*

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

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

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 60730-1:2013, *Automatic electrical controls for household and similar use — Part 1: General requirements*

IEC 60947-1, *Low-voltage switchgear and controlgear — Part 1: General rules*

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

IEC 60998-2-2, *Connecting devices for low-voltage circuits for household and similar purposes — Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60999-1, *Connecting devices — Electrical copper conductors — Safety requirements for screw-type and screwless-type clamping units — Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm2 up to 35 mm2 (included)*

IEC 60999-2, *Connecting devices — Electrical copper conductors — Safety requirements for screw-type and screwless-type clamping units — Part 2: Particular requirements for clamping units for conductors above 35 mm2 up to 300 mm2 (included)*

IEC 61010-1:2010, *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 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

IEC 61672-2, *Electroacoustics — Sound level meters — Part 2: Pattern evaluation tests*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
area classification
classification of *hazardous areas* (3.2) according to the probability of the existence of an explosive atmosphere, in order to relate the selection of electrical apparatus for use in the area to the degree of *hazard* (3.12)

3.2
hazardous area
area in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus

3.3
built-in hydrogen generator appliance
hydrogen generator intended to be installed in a cabinet, in a prepared recess in a wall, or in a similar location

3.4
commercial use
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

3.5
containment system
part of the apparatus containing a flammable substance that may constitute a source of release

3.6
dilution
continuous supply of a *purge gas* (3.27) at such a rate that the concentration of a flammable substance inside an *enclosure* (3.9) is maintained at a value outside the explosive (flammable) limits at any potential ignition source (that is to say, outside the dilution area)

3.7
dilution volume
location 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 to entry: *Dilution* (3.6) of oxygen by inert gas can result in a concentration of flammable gas or vapour above the upper flammability limit (UFL).

Note 2 to entry: Annex B provides information on the flammability limits of hydrogen.

3.8
electrochemical cell
assembly of electrodes, fluid containment, flow means, and electrical current conduction means that may include product gas separation *membranes* (3.19) and may be arranged as single unipolar cells or in bipolar cell stacks within or without a process containment vessel, for the purpose of producing hydrogen and/or oxygen from water

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
factory-matched
engineered in a factory to correspond with each other and work together, separately packed for storage and transportation, and intended to be assembled together at the point of utilization

[SOURCE: ISO 16110-1:2007, 3.21, modified — The term has been changed from "factory matched unit" to "factory-matched"; the words "system components" have been removed.]

3.12
hazard
potential source of harm

3.13
hazardous condition
condition that may adversely affect the safety of the hydrogen generator operation

Note 1 to entry: Examples of hazardous conditions include having an *enriched oxygen atmosphere* (3.10), a hydrogen concentration exceeding the lower flammability limit, an ignition source in a classified area, an overpressure, or an over temperature.

3.14
industrial use
use of hydrogen generators by qualified and experienced personnel in a controlled manufacturing or processing environment

3.15
ion transport medium
medium that provides ionic transport within the cell

3.16
maximum allowable working pressure
MAWP
maximum pressure permissible in a vessel or system at the temperature specified for the pressure

Note 1 to entry: The maximum allowable working pressure can also be defined as the design pressure, the maximum allowable operating pressure, the maximum permissible working pressure, or the maximum allowable pressure for the rating of pressure vessels and equipment manufactured in accordance with national pressure vessel codes.

3.17
maximum operating pressure
MOP
maximum pressure that can be expected by the pressure containing components when the hydrogen generator is functioning within its design and control parameters, including anticipated transients

3.18
mechanical ventilation
replacement of air inside an *enclosure* (3.9) with fresh air accomplished by a mechanical device (such as a fan) to prevent or eliminate hazardous concentrations of hydrogen

3.19
membrane
material that provides separation between oxygen and hydrogen product gases while allowing ionic transport within the cell

3.20
natural ventilation
replacement of air inside an *enclosure* (3.9) with fresh air accomplished exclusively by a natural draft caused, for example, by the effects of wind, temperature gradients or buoyancy effects, to prevent or eliminate hazardous concentrations of hydrogen

3.21
normal condition
condition in which all means for protection against *hazards* (3.12) are intact

3.22
normal use
operation, including stand-by, according to the instructions for use or for the obvious intended purpose

Note 1 to entry: In most cases, normal use also implies *normal condition* (3.21), because the instructions for use will warn against using the hydrogen generator when it is not in normal condition.

3.23
pressure relief device
PRD
device designed to release pressure in order to prevent a rise in pressure above a specified value due to emergency or abnormal conditions

Note 1 to entry: PRDs are activated by pressure or another parameter, such as temperature, and are either re-closing devices (such as valves) or non-re-closing devices (such as rupture disks and fusible plugs). Common designations for these specific types of PRDs are as follows:

— Pressure safety valve (PSV) — pressure activated valve that opens at a specified set point to protect a system from rupture and re-closes when the pressure falls below the set point.

— Temperature-activated pressure relief device (TPRD) — PRD that opens at a specified temperature to protect a system from rupture and remains open.

3.24
pressure-bearing component
part subject to a positive internal pressure of 100 kPa or greater

3.25
permanently connected
electrically connected to a supply by means of a permanent connection, which can be detached only by the use of a *tool* (3.34)

3.26
portable hydrogen generator
hydrogen generator that is not intended to be permanently fastened in a specific location and can be carried easily by a person

3.27
purge gas
gas used to maintain protective pressurization or to dilute flammable gas or vapour to a concentration well below the lower flammability limit

3.28
purging
passage of sufficient volume of a *purge gas* (3.27) through a pressurized *enclosure* (3.9) 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

3.29
residential use
use of hydrogen generators by laymen in private households (non-commercial and non-industrial use)

3.30
risk assessment
overall process of risk identification, risk analysis, risk evaluation, and risk mitigation

3.31
single fault condition
condition in which one means for protection against *hazards* (3.12) is defective or one fault is present which could cause a hazard

Note 1 to entry: If a single fault condition results unavoidably in another single fault condition, the two failures are considered as one single fault condition.

3.32
standard 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 absolute pressure of 100 kPa

3.33
supply cord
flexible cord, for supply purposes, that is fixed to the hydrogen generator

3.34
tool
external device, including keys and coins, used to aid a person to perform a mechanical function

4 Requirements

4.1 Operating conditions

4.1.1 Energy consumption

4.1.1.1 Electrical

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

4.1.1.2 Other utilities

The manufacturer shall specify any other utilities required.

4.1.2 Feed water specifications

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

4.1.3 Ambient environment

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

4.1.4 Purge gas

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

4.1.5 Oxygen venting

4.1.5.1 General

The manufacturer shall specify if oxygen is to be vented indoors or outdoors. If oxygen is to be vented indoors, the manufacturer shall specify if oxygen is to be vented directly out of the enclosure or within the enclosure. Oxygen vents shall meet the IP rating of 4.3.9.

4.1.5.2 Oxygen vented outdoors

If oxygen is vented outdoors, it shall be vented out of any enclosure to an outdoor location in a way that will not create a hazardous condition. The installation instructions shall provide full details describing acceptable methods as required by 7.3.1.

4.1.5.3 Oxygen vented within enclosures or indoors

To preclude the formation of a hazardous enriched-oxygen atmosphere within an enclosure, oxygen purposely vented inside the enclosure shall be diluted by a ventilation air stream to a volume fraction of oxygen in air of less than 23,5 % before being exhausted from the enclosure. For electrical equipment that could come in contact with enriched-oxygen mixtures, see 4.4.1.5.

For systems venting oxygen into either the enclosure or indoors, room ventilation guidance to preclude a room oxygen concentration in air above a volume fraction of 23,5 % shall be provided in the installation instructions as required by 7.3.3. A label warning about the presence of oxygen shall be affixed as required by 6.4.

The design of the enclosure ventilation shall dilute the oxygen concentration such that any gas flow exiting the 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 shall be provided and cause the hydrogen generator to shut down.

In residential applications, oxygen shall not be vented indoors directly through tubing or piping in a way that facilitates oxygen product collection (see 4.1.8). The manufacturer shall provide instruction and warnings to exclude oxygen collection per 7.3.1.

Pressure relief devices that vent within enclosures or indoors shall be considered when determining dilution and ventilation requirements.

4.1.6 Hydrogen venting

4.1.6.1 General

Hydrogen shall be vented in a manner that will not create a hazardous condition in accordance with 4.1.6.2 and 4.1.6.3. Hydrogen vents shall meet the IP rating of 4.3.9.

4.1.6.2 Hydrogen vented outdoors

Means shall be provided to connect a hydrogen vent line to the hydrogen generator. When supplied with the hydrogen generator, vent lines should be designed according to ISO/TR 15916, or other similar standards.

NOTE Additional guidance on hydrogen vents can be found in CGA G-5.5 and EIGA Doc 211/17.

4.1.6.3 Hydrogen vented within enclosures or indoors

Hydrogen gas may be vented within enclosures if it is diluted to a volume fraction of hydrogen in air of less than 1 % before exiting the enclosure.

Room ventilation guidance to preclude a room hydrogen concentration in air above a volume fraction of 1 % shall be provided in the installation instructions as required by 7.3.3 and a label warning about the presence of hydrogen shall be affixed as required by 6.4.

4.1.7 Delivery of hydrogen

The manufacturer shall specify the hydrogen production rate, the hydrogen output pressure range, hydrogen temperature range, and the hydrogen quality under standard conditions.

NOTE ISO 14687 includes specifications for hydrogen quality for use in representative applications.

4.1.8 Delivery of oxygen

Industrial and commercial equipment may deliver oxygen. Where applicable, the manufacturer shall specify the oxygen production rate, the oxygen output pressure range, hydrogen temperature range, and the quality of the oxygen produced by the hydrogen generator at standard conditions.

Residential hydrogen generators shall not deliver oxygen.

4.2 Risk management

The manufacturer shall perform a risk assessment on the hydrogen generator design using one or more structured techniques per IEC 31010:2019, Annex B and/or the requirements of ISO 12100.

It is recommended that the risk assessment be quantitative or semi-quantitative. As a minimum, mitigation measures shall address single faults that present a hazard or risk. (refer to 4.5) The risk assessment shall demonstrate that the mitigation measures are appropriate to achieve the desired reduction of the probability and/or consequences of each risk scenario. The risk assessment shall demonstrate that all mitigation measures employed are appropriate to achieve the desired level of risk for the hydrogen generator.

NOTE 1 It is possible that individual mitigation measures interact to affect the probability and/or impact of multiple aspects of the analysis. For example, use of enclosures can reduce the probability of ignition, but can also potentially increase the consequence of deflagrations.

NOTE 2 It is possible that regulation prescribes the risk assessment methods and the degree of detail of the risk assessment analysis. For example, per national regulations, it is possible the operator must carry out further risk assessment, or layers of protection analysis (LOPA) for the hydrogen generator.

NOTE 3 It is possible that the owner/operator performs a final risk assessment of the hydrogen generator based on the specific location of the hydrogen generator.

Hydrogen generators shall be designed and manufactured such that where a release of flammable gas occurs during normal operation, the formation of a flammable atmosphere is prevented, minimized, detected, and/or controlled. Hydrogen generators shall be manufactured such that unintentional hydrogen releases are minimized (see IEC 60079 and 4.4.1).

4.3 Mechanical equipment

4.3.1 General requirements

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