INTERNATIONAL STANDARD

ISO 16110-2

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Hydrogen generators using fuel processing technologies —

Part 2: Test methods for performance

Générateurs d'hydrogène faisant appel aux technologies du traitement du carburant —

Partie 2: Méthodes d'essai de rendement

Reference number
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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 16110-2 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies.*

ISO 16110 consists of the following parts, under the general title *Hydrogen generators using fuel processing technologies*:

— *Part 1: Safety*

— *Part 2: Test methods for performance*

Introduction

This part of ISO 16110 describes how to measure and document the performance of stationary hydrogen generators for residential, commercial and industrial applications.

The following hydrogen generation types have been considered:

— hydrogen generators using fuel processing technologies.

Hydrogen generators using fuel processing technologies —

Part 2:
Test methods for performance

1 Scope

This part of ISO 16110 provides test procedures for determining the performance of packaged, self-contained or factory matched hydrogen generation systems with a capacity less than 400 m^3/h at 0 °C and 101,325 kPa, herein referred to as hydrogen generators, that convert a fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device using the hydrogen (e.g. a fuel cell power system, or a hydrogen compression, storage and delivery system).

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 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

ISO 4677 (all parts), *Atmospheres for conditioning and testing — Determination of relative humidity*

ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

ISO 6060, *Water quality — Determination of the chemical oxygen demand*

ISO 6326 (all parts), *Natural gas — Determination of sulfur compounds*

ISO 6974 (all parts), *Natural gas — Determination of composition with defined uncertainty by gas chromatography*

ISO 6975, *Natural gas — Extended analysis — Gas-chromatographic method*

ISO 7934, *Stationary source emissions — Determination of the mass concentration of sulfur dioxide — Hydrogen peroxide/barium perchlorate/Thorin method*

ISO 9096, *Stationary source emissions — Manual determination of mass concentration of particulate matter*

ISO 10101 (all parts), *Natural gas — Determination of water by the Karl Fischer method*

ISO 10523, *Water quality — Determination of pH*

ISO 10707, *Water quality — Evaluation in an aqueous medium of the “ultimate” aerobic biodegradability of organic compounds — Method by analysis of biochemical oxygen demand (closed bottle test)*

ISO 11042 (all parts), *Gas turbines — Exhaust gas emission*

ISO 11541, *Natural gas — Determination of water content at high pressure*

ISO 11564, *Stationary source emissions — Determination of the mass concentration of nitrogen oxides — Naphthylethylenediamine photometric method*

ISO 14687-1, *Hydrogen fuel — Product specification — Part 1: All applications except proton exchange membrane (PEM) fuel cell for road vehicles*

ISO 14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

ISO 16622, *Meteorology — Sonic anemometers/thermometers — Acceptance test methods for mean wind measurements*

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements*

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

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
audible noise level
sound pressure level produced by the hydrogen generator measured at a specified distance

NOTE Audible noise level is expressed as decibels (dBA) and measured as described in this part of ISO 16110.

3.1.2
background noise level
sound pressure level of ambient noise at the measurement point

3.1.3
cold state
condition of a hydrogen generator at ambient temperature with no substantial fuel or power input

3.1.4
discharge water
water that is released by the hydrogen generator

NOTE Discharge water does not constitute part of a thermal recovery system. It is comprised of the water treatment waste and the process condensate shown in Figure 1.

3.1.5
hydrogen generator
system that converts a fuel to a hydrogen-rich stream

NOTE The hydrogen generator is composed of all or some of the following subsystems: a fuel processing system, a fluid management system, a thermal management system, and other subsystems as described in more detail in ISO 16110-1.

3.1.6
interface point
measurement point of a hydrogen generator at which material and/or energy either enters or leaves

3.1.7
return gas
tail gas
unused reformed hydrogen-rich gas, which returns to the hydrogen generator and is used as a fuel

NOTE Return gas generally includes hydrogen, carbon dioxide, water vapour and slipped hydrocarbon.

3.1.8
standby state
state in which the hydrogen generator is at operating temperature and is in an operational mode from which it can be promptly switched to an operational mode with net hydrogen output

See Figure 2, item 2.

3.1.9
start-up time
time from cold start to supply of hydrogen gas at the rated hydrogen pressure

See Figure 2, item 1-3.

3.1.10
waste heat
thermal energy released and not recovered

3.2 Symbols

The symbols and their meanings are described in Annex A.

4 Test conditions/Test boundary

Hydrogen generators may have different subsystems depending on types of primary conversion processes and applications, and they have different streams of material and energy in and out of them. However, a common system diagram and boundary has been defined for evaluation of the hydrogen generator (see Figure 1).

The following conditions shall be considered in order to determine the test boundary of the hydrogen generator:

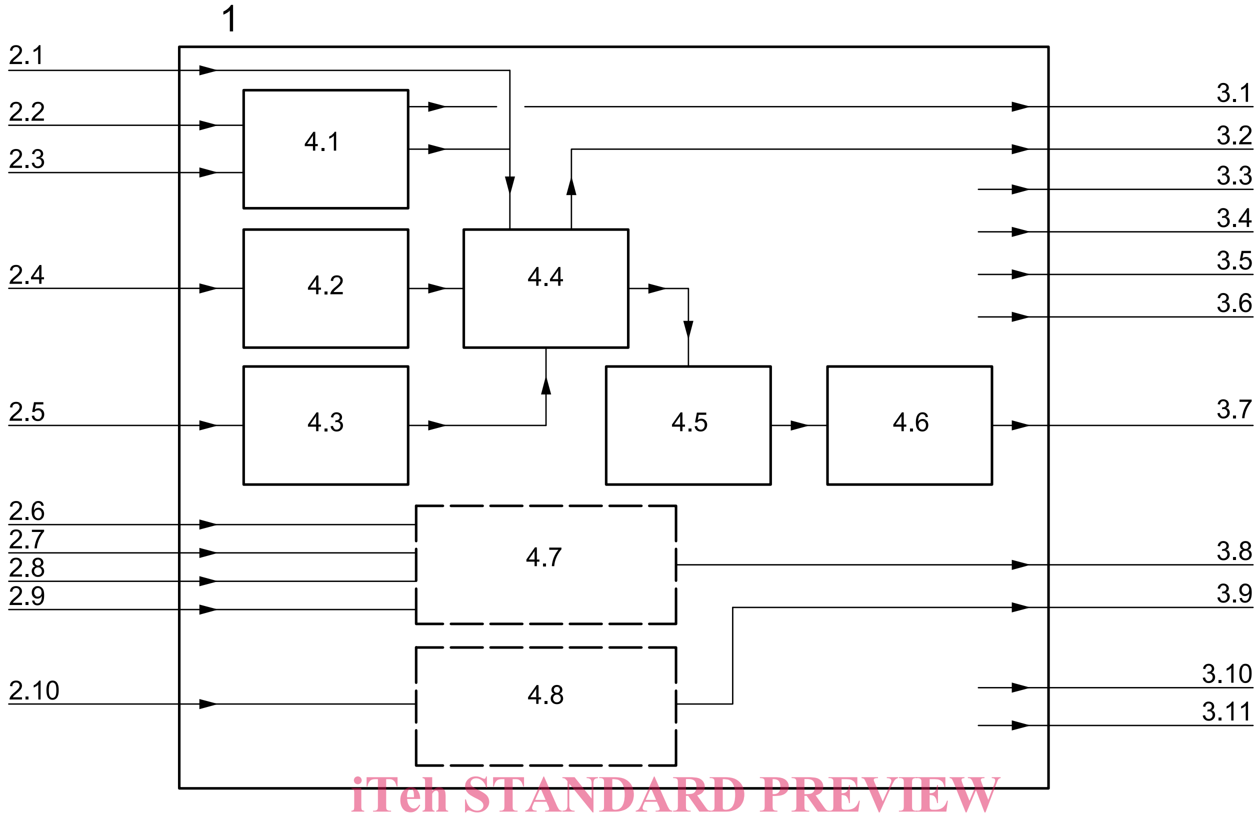
— All energy recovery systems shall be included within the system boundary.

— Calculation of the heating value of the input fuel (such as natural gas, propane gas, etc.) shall be based on the conditions of the input fuel at the boundary of the hydrogen generator.

— Calculation of the heating value of the output hydrogen containing gas stream shall be based on the conditions of the gas stream at the boundary of the hydrogen generator.

— Mechanical systems required for hydrogen generator operation (i.e. ventilation or micro-turbines, expanders or compressors) shall be included inside the test boundary. The direct measurement of these mechanical systems inside the test boundary is not required; however, their effects shall be included in the hydrogen generator operation. If mechanical (shaft) power and energy cross the test boundary, additional measurements and calculations may be necessary.

  NOTE This part of ISO 16110 does not take into account mechanical (shaft) power or mechanical energy inputs or outputs.



1 **system boundary of the hydrogen generator** including subsystems and the interface is defined as a conceptual or functional one

2	**inputs**	3	**outputs**
2.1	steam (if imported)	3.1	water treatment waste
2.2	water	3.2	exhaust gas
2.3	treatment chemicals	3.3	process vents
2.4	air/oxidant	3.4	recovered heat
2.5	fuel	3.5	process condensate
2.6	purge gas	3.6	solid waste
2.7	cooling fluid	3.7	hydrogen
2.8	instrument gas	3.8	cooling fluid
2.9	electrical power input	3.9	ventilation exhaust
2.10	atmospheric air	3.10	noise
		3.11	waste heat

4 **subsystems** (the configurations depend on the kind of fuel, type of fuel cell or system)

4.1 water treatment and steam generation
4.2 air/oxidant processing system
4.3 feedstock compression and processing
4.4 fuel processing system
4.5 hydrogen purification (optional)
4.6 hydrogen metering and analysis
4.7 process utilities (cooling fluid, purge gas, instrument gas, electrical, etc.)
4.8 ventilation system

→: **The interface points** in the boundary to be measured for calculation data.

NOTE The fuel input can also consist of return gas.

Figure 1 — Typical hydrogen generator diagram

5 Measurement technique

5.1 General

The types of measuring instruments and measurement methods shall conform to the relevant International Standards and shall be selected to meet the measurement uncertainty targets in line with the uncertainty analysis of 6.4. If necessary, external equipment with required specification shall be added.

5.2 Operational parameters

5.2.1 Electrical power input

The electrical power input to the hydrogen generator, the voltage, the current and the power factor shall be determined and measured in accordance with IEC 61010-1.

5.2.2 Input and output fluid characteristics

5.2.2.1 General

The composition, the heating value (only for fuels), the temperature, the pressure and the flow rate of the input and output fluids shall be determined as per 5.2.2.2 to 5.2.2.6.

If there is fluctuation greater than ± 2 % in any measured value, the amplitude and the frequency of the fluctuation shall be measured and reported as part of the test results.

5.2.2.2 Composition of fluids

The composition of each input and output fluid shall be measured. The measurement technique shall be appropriate to the chemical composition of the fluid in question. If the fluid is not critical to operability or utility consumption, direct measurement of the fluid composition shall not be required for conformance with this part of ISO 16110.

If the only chemical oxidant employed is atmospheric air, only the moisture content shall be measured. The moisture content value may be calculated from other direct measurements (e.g. wet bulb and dry bulb temperatures) and reported as relative humidity.

The composition of natural gas shall be measured in accordance with methods detailed in ISO 6974 and ISO 6975.

The sulfur compounds (including odorant) of natural gas shall be measured according to methods detailed in ISO 6326.

The water vapour content of natural gas shall be measured according to methods detailed in ISO 10101 and ISO 11541.

The hydrogen composition shall be determined using the test methods specified in ISO 14687-1 or ISO 14687-2, as applicable.

The composition of other fluids shall be measured in accordance with the standard(s) appropriate to the fluids.

5.2.2.3 Heating value

The heating value of the input and output fluids shall only be measured for combustible fluids. The heating value shall be determined through either calorimetric methods, or via calculation based on the fluid composition as specified in Clause 8. The accuracy and detection limits of the composition measurement technique shall be determined, and its effect on the uncertainty analysis of 6.4 shall be explicitly considered. Pre-analysed bottled fuel gas may be substituted for gas sampling, provided that the uncertainty of the analysed gas is consistent with the uncertainty required by the uncertainty analysis of 6.4.

In principle, the lower heating value (LHV) shall be used for all the calculations defined in this part of ISO 16110. Should the higher heating value (HHV) be applied instead of LHV, the abbreviation “HHV” shall be added to all the results that derive from the use of the HHV, such as the heating value of gaseous fuel calculated as per Equation (15), the energy of gaseous fuel calculated as per Equation (16), the input energy of gaseous fuel calculated as per Equation (15) and the efficiency calculated as per Annex D.

EXAMPLE If the value of efficiency is based on the HHV, it should be expressed as follows:

$\eta_h = XX\%$ (HHV)

NOTE In case of LHV, it is not necessary to add the abbreviation “LHV”.

5.2.2.4 Temperature

The temperature of each fluid shall be measured at the boundary of the hydrogen generator.

5.2.2.5 Pressure

The static pressure of each fluid shall be measured at the boundary of the hydrogen generator.

The height above grade shall be measured and recorded for input and output liquids.

The potential effects of condensable fractions shall be considered in the uncertainty analysis of 6.4 and in the location of the pressure measurement means.

If the discharge of a particular fluid is to the atmosphere, its pressure need not be measured.

5.2.2.6 Flow rate

The flow rate of each fluid shall be measured at the boundary of the hydrogen generator.

Flow rates may be determined by means of a volumetric meter, mass flow meter or turbine type flow meter. If such a method is not practicable, flow measurement by nozzles, orifices or venturi meters should be used and they shall be applied in accordance with ISO 5167.

If a particular fluid is not chemically modified in the hydrogen generator, such as cooling fluid, instrument air or purge gas, only the input or output flow rate shall be measured.

The effects of the flow measurement on the operability of the hydrogen generator shall be considered.

5.2.3 Solid output characteristics

Any solid outputs from the hydrogen generator, which is generated on a continuous basis, and which have to be removed or disposed of continuously or in a repetitive batch operation, shall be characterized. The following properties shall be measured:

a) composition;

b) mass generation rate;

c) frequency of removal, if a batch operation is necessary.

5.3 Environmental aspects

5.3.1 Particulate emission

Particulate emission in the exhaust gases shall be measured in accordance with ISO 9096.

5.3.2 SOx and NOx emission

5.3.2.1 SOx emission

SOx emission in the exhaust gases shall be measured in accordance with ISO 7934. Other methods suitable for the service may be used providing they are consistent with the uncertainty analysis of 6.4.

5.3.2.2 NOx emission

NOx emission in the exhaust gases shall be measured in accordance with ISO 11564. Other methods suitable for the service may be used providing they are consistent with the uncertainty analysis of 6.4.

5.3.3 CO_2 and CO emission

CO_2 emission in the exhaust gases shall be measured in accordance with ISO 11042-1 and ISO 11042-2. CO_2 may be calculated based on carbon content of the fuel.

CO emission in the exhaust gases shall be measured in accordance with ISO 11042-1 and ISO 11042-2.

5.3.4 Total hydrocarbon emission

Total hydrocarbon emission in the exhaust gases shall be measured in accordance with ISO 11042-1 and ISO 11042-2.

5.3.5 Discharge water quality measurement

5.3.5.1 General

Quality measurements for water discharged from a hydrogen generator shall include the determination of:

a) volume of discharge water;

b) temperature of discharge water;

c) pH;

d) chemical oxygen demand (COD) or, if necessary, biochemical oxygen demand (BOD).

5.3.5.2 pH

The pH shall be measured in accordance with ISO 10523.

5.3.5.3 Chemical oxygen demand (COD)

The COD shall be measured in accordance with ISO 6060.

5.3.5.4 Biochemical oxygen demand (BOD)

When applicable, the BOD shall be measured in accordance with ISO 10707.