



BSI Standards Publication

Fuel cell technologies

Part 3-200: Stationary fuel cell power systems — Performance test methods

National foreword

This British Standard is the UK implementation of EN IEC 62282-3-200:2025. It is identical to IEC 62282-3-200:2025. It supersedes BS EN 62282-3-200:2016, which will be withdrawn on 30 November 2028.

The UK participation in its preparation was entrusted to Technical Committee GEL/105, Fuel cell technologies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Fuel cell technologies - Part 3-200: Stationary fuel cell power
systems - Performance test methods
(IEC 62282-3-200:2025)

Technologies des piles à combustible - Partie 3-200:
Systèmes à piles à combustible stationnaires - Méthodes
d'essai des performances
(IEC 62282-3-200:2025)

Brennstoffzellentechnologien - Teil 3-200: Stationäre
Brennstoffzellen-Energiesysteme -
Leistungskennwerteproofverfahren
(IEC 62282-3-200:2025)

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 105/1124/FDIS, future edition 3 of IEC 62282-3-200, prepared by TC 105 "Fuel cell technologies" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62282-3-200:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2026-11-30 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2028-11-30 document have to be withdrawn

This document supersedes EN 62282-3-200:2016 and all of its amendments and corrigenda (if any).

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

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 62282-3-200:2025 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

ISO 9000 NOTE Approved as EN ISO 9000

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60051	series	Direct acting indicating analogue electrical measuring instruments and their accessories	EN 60051	series
IEC 60359	-	Electrical and electronic measurement equipment - Expression of performance	EN 60359	-
IEC 60688	-	Electrical measuring transducers for converting AC and DC electrical quantities to analogue or digital signals	EN IEC 60688	-
IEC 61000-4-7	-	Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto	EN 61000-4-7	-
IEC 61028	-	Electrical measuring instruments - X-Y recorders	EN 61028	-
IEC 61143	series	Electrical measuring instruments - X-t recorders	EN 61143	series
IEC 61672-1	-	Electroacoustics - Sound level meters - Part 1: Specifications	EN 61672-1	-
IEC 61672-2	-	Electroacoustics - Sound level meters - Part 2: Pattern evaluation tests	EN 61672-2	-
IEC 62052-11	-	Electricity metering equipment - General requirements, tests and test conditions - Part 11: Metering equipment	EN IEC 62052-11	-
IEC 62053-22	-	Electricity metering equipment - Particular requirements - Part 22: Static meters for AC active energy (classes 0,1S, 0,2S and 0,5S)	EN IEC 62053-22	-

EN IEC 62282-3-200:2025 (E)

IEC 62282-3-201	-	Fuel cell technologies - Part 3-201: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems	EN IEC 62282-3-201	-
ISO 3648	-	Aviation fuels - Estimation of net specific energy	-	-
ISO 3744	-	Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane	EN ISO 3744	-
ISO 4677-1	-	Atmospheres for conditioning and testing; Determination of relative humidity; Part 1 : Aspirated psychrometer method	-	-
ISO 4677-2	-	Atmospheres for conditioning and testing; Determination of relative humidity; Part 2 : Whirling psychrometer method	-	-
ISO 5167	series	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full	EN ISO 5167	series
ISO 5348	-	Mechanical vibration and shock - Mechanical mounting of accelerometers	-	-
ISO 5815-2	-	Water quality - Determination of biochemical oxygen demand after n days (BOD _n) – Part 2: Method for undiluted samples	-	-
ISO 6060	-	Water quality; determination of the chemical oxygen demand	-	-
ISO 6974	series	Natural gas - Determination of composition and associated uncertainty by gas chromatography	EN ISO 6974	series
ISO 6975	-	Natural gas - Extended analysis - Gas-chromatographic method	EN ISO 6975	-
ISO 7934	-	Stationary source emissions; determination of the mass concentration of sulfur dioxide; hydrogen peroxide/barium perchlorate/thorin method	-	-
ISO 7935	-	Stationary source emissions - Determination of the mass concentration of sulfur dioxide in flue gases - Performance characteristics of automated measuring systems	-	-
ISO 8217	2024	Products from petroleum, synthetic and renewable sources - Fuels (class F) - Specifications of marine fuels	-	-
ISO 10101	series	Natural gas - Determination of water by the Karl Fisher method	EN ISO 10101	series
ISO 10396	-	Stationary source emissions - Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems	-	-
ISO 10523	-	Water quality -- Determination of pH	EN ISO 10523	-

ISO 11626	-	Natural gas - Determination of sulfur compounds - Determination of hydrogen sulfide content by UV absorption method		
ISO 10849	-	Stationary source emissions - Determination of the mass concentration of nitrogen oxides in flue gas - Performance characteristics of automated measuring systems	-	-
ISO 11042-1	-	Gas turbines - Exhaust gas emission -- Part 1: Measurement and evaluation	-	-
ISO 11042-2	-	Gas turbines - Exhaust gas emission -- Part 2: Automated emission monitoring	-	-
ISO 11541	-	Natural gas - Determination of water content at high pressure	EN ISO 11541	-
ISO 11564	-	Stationary source emissions - Determination of the mass concentration of nitrogen oxides - Naphthylethylenediamine photometric method	-	-
ISO 11632	-	Stationary source emissions - Determination of mass concentration of sulfur dioxide - Ion chromatography method	-	-
ISO 14687	-	Hydrogen fuel quality - Product specification	-	-
ISO/TR 15916	-	Basic considerations for the safety of hydrogen systems	-	-
ISO 16622	-	Meteorology - Sonic anemometers/thermometers - Acceptance test methods for mean wind measurements	-	-
ISO 16960	-	Natural gas - Determination of sulfur compounds - Determination of total sulfur by oxidative microcoulometry method	EN ISO 16960	-
ISO 19739	-	Natural gas - Determination of sulfur compounds using gas chromatography	EN ISO 19739	-
ISO 20729	-	Natural gas - Determination of sulfur compounds - Determination of total sulfur content by ultraviolet fluorescence method		
ASTM D4809	-	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**Fuel cell technologies -
Part 3-200: Stationary fuel cell power systems -
Performance test methods****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62282-3-200 has been prepared by IEC technical committee 105: Fuel cell technologies. It is an International Standard.

This third edition cancels and replaces the second edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) revision of the Introduction, Scope and Clause 3;
- b) revision of the symbols in Table 1;
- c) revision of Figure 2 (symbol diagram);
- d) revision of measurement methods (8.3);
- e) revision of the efficiency test (10.2);

- f) revision of the electric power and thermal power response characteristics test (10.3);
- g) revision of the start-up and shutdown characteristics test (10.4);
- h) revision of Annex C.

The text of this International Standard is based on the following documents:

Draft	Report on voting
105/1124/FDIS	105/1134/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This part of IEC 62282 describes how to measure the performance of stationary fuel cell power systems for residential, commercial, agricultural and industrial applications.

This document describes type tests and their test methods only. In this document, no routine tests are required or identified, and no performance targets are set.

A related but independent standard IEC 62282-3-201 on the performance test methods of small stationary fuel cell power systems has been aligned with this document.

1 Scope

This part of IEC 62282 covers operational and environmental aspects of the stationary fuel cell power systems performance. The test methods apply as follows:

- power output under specified operating and transient conditions;
- electrical and heat recovery efficiency under specified operating conditions;
- environmental characteristics, for example, exhaust gas emissions, noise, under specified operating and transient conditions.

This document applies to all kinds of stationary fuel cell technologies, such as:

- alkaline fuel cells (AFC);
- phosphoric acid fuel cells (PAFC);
- polymer electrolyte fuel cells (PEFC);
- molten carbonate fuel cells (MCFC);
- solid oxide fuel cells (SOFC).

This document does not provide coverage for electromagnetic compatibility (EMC).

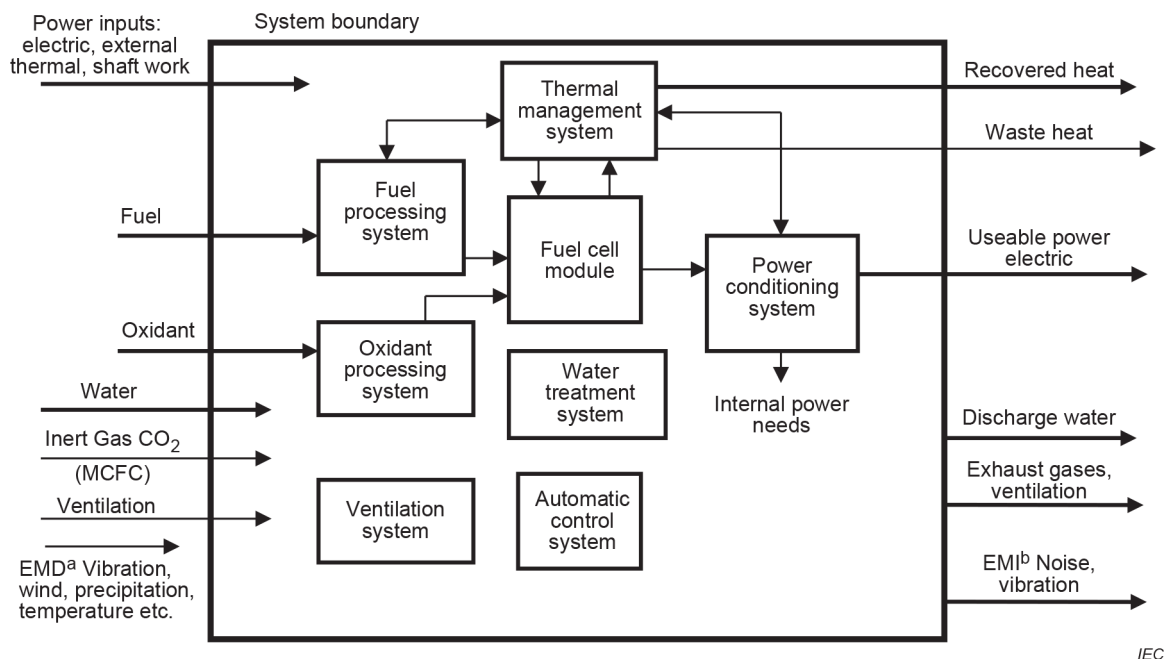
This document does not apply to small stationary fuel cell power systems with rated electric power output of less than 10 kW which are dealt with in IEC 62282-3-201.

Fuel cell power systems can have different subsystems depending upon types of fuel cell and applications, and they have different streams of material and energy into and out of them. However, a common system diagram and boundary has been defined for evaluation of the fuel cell power system (see Figure 1).

The following conditions are considered in order to determine the system boundary of the fuel cell power system:

- all energy recovery systems are included within the system boundary;
- all kinds of electric energy storage devices are considered outside the system boundary;
- calculation of the heating value of the input fuel (such as natural gas, propane gas and pure hydrogen gas) is based on the conditions of the fuel at the boundary of the fuel cell power system.

The document does not provide safety requirements for the testing of stationary fuel cell power systems. Details on safe operation of the tested system can be obtained from the manufacturers instructions.

**Key**

Fuel cell power system including subsystems. The interface is defined as a conceptual or functional one instead of hardware such as a power package.



Subsystems: fuel cell module, fuel processor, etc. These subsystem configurations depend on the kind of fuel, type of fuel cell or system.



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

^a EMD electromagnetic disturbance

^b EMI electromagnetic interference

Figure 1 – Fuel cell power system diagram

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.

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60359, *Electrical and electronic measurement equipment - Expression of performance*

IEC 60688, *Electrical measuring transducers for converting AC and DC electrical quantities to analogue or digital signals*

IEC 61000-4-7, *Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61028, *Electrical measuring instruments - X-Y recorders*

IEC 61143 (all parts), *Electrical measuring instruments - X-t recorders*

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

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

IEC 62052-11, *Electricity metering equipment - General requirements, tests and test conditions - Part 11: Metering equipment*

IEC 62053-22, *Electricity metering equipment - Particular requirements - Part 22: Static meters for AC active energy (classes 0,1S, 0,2S and 0,5S)*

IEC 62282-3-201, *Fuel cell technologies - Part 3-201: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems*

ISO 3648, *Aviation fuels - Estimation of net specific energy*

ISO 3744, *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane*

ISO 4677-1, *Atmospheres for conditioning and testing - Determination of relative humidity - Part 1: Aspirated psychrometer method*

ISO 4677-2, *Atmospheres for conditioning and testing - Determination of relative humidity - Part 2: Whirling psychrometer method¹*

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

ISO 5348, *Mechanical vibration and shock - Mechanical mounting of accelerometers*

ISO 5815-2, *Water quality - Determination of biochemical oxygen demand after n days (BOD_n) - Part 2: Method for undiluted samples*

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

ISO 6974 (all parts), *Natural gas - Determination of composition and associated 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 7935, *Stationary source emissions - Determination of the mass concentration of sulfur dioxide in flue gases - Performance characteristics of automated measuring systems*

ISO 8217:2024, *Products from petroleum, synthetic and renewable sources - Fuels (class F) - Specifications of marine fuels*

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

¹ This publication was withdrawn.

ISO 10396, *Stationary source emissions - Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems*

ISO 10523, *Water quality - Determination of pH*

ISO 11626, *Natural gas - Determination of sulfur compounds - Determination of hydrogen sulfide content by UV absorption method*

ISO 10849, *Stationary source emissions - Determination of the mass concentration of nitrogen oxides in flue gas - Performance characteristics of automated measuring systems*

ISO 11042-1, *Gas turbines - Exhaust gas emission - Part 1: Measurement and evaluation*

ISO 11042-2, *Gas turbines - Exhaust gas emission - Part 2: Automated emission monitoring*

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 11632, *Stationary source emissions - Determination of mass concentration of sulfur dioxide - Ion chromatography method*

ISO 14687, *Hydrogen fuel - Product specification*

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

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

ISO 16960, *Natural gas - Determination of sulfur compounds - Determination of total sulfur by oxidative microcoulometry method*

ISO 19739, *Natural gas - Determination of sulfur compounds using gas chromatography*

ISO 20729, *Natural gas - Determination of sulfur compounds - Determination of total sulfur content by ultraviolet fluorescence method*

ASTM D4809, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

auxiliary electric power input

electric power for auxiliary machines and equipment supplied from outside the system boundary

3.1.2

background noise level

sound pressure level of ambient noise at the measurement point

Note 1 to entry: This measurement is taken as described in this document with the fuel cell power system in the cold state.

3.1.3

background vibration level

mechanical oscillations level caused by the environment that affect vibration level readings

Note 1 to entry: In this document, background vibration is measured with the fuel cell power system in the cold state.

3.1.4

cold state

state of a fuel cell power system, which is entirely at ambient temperature with no power input or output, ready for start-up

Note 1 to entry: Power input to a control device for monitoring the fuel cell power system during cold state is not taken into consideration.

[SOURCE: IEC 60050-485:2020, 485-21-01, modified – "which is entirely" and "ready for start-up" added; Note 1 to entry added.]

3.1.5

discharge water

water discharged from the fuel cell power system including waste water and condensate

3.1.6

electrical efficiency

ratio of the average net electric power output produced by a fuel cell power system to the average total power input supplied to the fuel cell power system

Note 1 to entry: Lower heating value (LHV) is assumed unless otherwise stated.

Note 2 to entry: Any electric power that is supplied to auxiliary machines and equipment of a fuel cell power system from an external source is deducted from the electric power output of the fuel cell power system.

[SOURCE: IEC 60050-485:2020, 485-10-02, modified – "electrical" instead of "electric" in the preferred term; "average net electric power output" instead of "net electric power"; "average total power input" instead of "total enthalpy flow"; "Note 2 to entry added.]

3.1.7

external thermal energy

additional thermal energy input from outside the system boundary

Note 1 to entry: External thermal energy can be supplied e.g. by make-up water or process condensate return.

3.1.8**fuel cell module**

assembly incorporating one or more fuel cell stacks and, if applicable, additional components, that is intended to be integrated into a power system

Note 1 to entry: A fuel cell module comprises the following main components: one or more fuel cell stack(s), a piping system for conveying fuels, oxidants and exhausts, electric connections for the power delivered by the stack(s), and means for monitoring, control or both. Additionally, a fuel cell module can comprise: means for conveying additional fluids (e.g. cooling media, inert gas, CO₂ (MCFC)), means for detecting normal and abnormal operating conditions, enclosures or pressure vessels and module ventilation systems, and the required electronic components for module operation and power conditioning.

[SOURCE: IEC 60050-485:2020, 485-09-03, modified – In the definition "or a vehicle" deleted and in the Note to entry, "CO₂ (MCFC)" added.]

3.1.9**fuel cell power system**

generator system that uses one or more fuel cell modules to generate electric power and heat

Note 1 to entry: A fuel cell power system is composed of all or some of the systems shown in Figure 1.

[SOURCE: IEC 60050-485:2020, 485-09-01, modified – Note 1 to entry added.]

3.1.10**fuel input**

amount of natural gas, hydrogen, methanol, liquid petroleum gas, propane, butane, or other substance containing chemical energy introduced to the fuel cell power system during specified operating conditions

3.1.11**heat recovery efficiency**

ratio of the average recovered thermal power output of a fuel cell power system to the average total power input supplied to the fuel cell power system

[SOURCE: IEC 60050-485:2020, 485-10-04, modified – "average recovered thermal power output" instead of "recovered heat flow"; "average total power input" instead of "total enthalpy flow"; Note 1 to entry deleted.]

3.1.12**interface point**

measurement point at the boundary of a fuel cell power system at which material or energy, or both, either enters or leaves

Note 1 to entry: This boundary is intentionally selected to accurately measure the performance of the system including all normal operation, both steady state and transient. If necessary, the boundary or the interface points of the fuel cell power system (Figure 1) to be assessed should be determined by agreement between the parties.

[SOURCE: IEC 60050-485:2020, 485-09-12, modified – In Note 1 to entry, reference to Figure 1 added and Note 2 to entry deleted.]

3.1.13**minimum power**

lowest net electric power output at which a fuel cell power system is able to operate continuously in a stable manner

[SOURCE: IEC 60050-485:2020, 485-14-02, modified – "output" added, Note 1 to entry deleted.]

3.1.14**noise level**

sound pressure level produced by a fuel cell power system

Note 1 to entry: Noise level is expressed in decibels (dB) and measured at a specified distance and in all operation modes as described in this document.

3.1.15**operating temperature**

temperature at which the fuel cell power system operates and with its determination specified by the manufacturer

Note 1 to entry: The temperature can be either measured at a specific measuring point or determined from the measurement at several specific points.

3.1.16**overall energy efficiency**

ratio of total useable power output (net electrical power and recovered thermal power) to the average total power input supplied to the fuel cell power system

Note 1 to entry: The supplied total power input of the fuel should be related to the lower heating value (LHV) for a better comparison with other types of energy conversion systems.

Note 2 to entry: Refer to 4.3 regarding reporting based on LHV or HHV.

[SOURCE: IEC 60050-485:2020, 485-10-05, modified – Second preferred term "total thermal efficiency" deleted; in the definition, "power output" instead of "energy flow"; "thermal power" instead of "heat flow"; "average total power input" instead of "total enthalpy flow"; in Note 1 to entry, "total power input" instead of "total (including reaction enthalpy) enthalpy flow" and Note 2 to entry added.]

3.1.17**oxidant input**

amount of oxidant (air) input into the inside of the fuel cell module during specified operating conditions

Note 1 to entry: The oxidant is usually air, but other oxidants (e.g. oxygen) can be used.

3.1.18**power response time**

duration between the instant of initiating a change of electric or thermal power output and when the electric or thermal power output attains the set value within tolerance

3.1.19**90 % power response time**

duration between the instant of initiating a change of electric or thermal power output and when the electric or thermal power output attains 90 % of the desired value within tolerance

3.1.20**pre-generation state**

state of a fuel cell power system at a sufficient operating temperature and in such an operational mode, with zero electric power output, that the fuel cell power system is capable of being promptly switched to an operational state with a substantial net electric power output

[SOURCE: IEC 60050-485:2020, 485-21-04, modified – second preferred term "pre-generation operation" deleted and in the definition, "net" added before "electric"]

3.1.21**purge gas consumption**

amount of inert gas or dilution gas supplied to the fuel cell power system during specific conditions to make it ready for operation or shutdown

3.1.22

net electric power output

power generated by the fuel cell power system and available for external use

[SOURCE: IEC 60050-485:2020, 485-14-03, modified – "output" added to the preferred term, Notes 1 and 2 to entry deleted.]

3.1.23

rated power

maximum continuous electric power output that a fuel cell power system is designed to achieve under normal operating conditions specified by the manufacturer

[SOURCE: IEC 60050-485:2020, 485-14-04, modified – "Note 1 to entry" deleted.]

3.1.24

recovered heat

thermal energy that is recovered for useful purposes

Note 1 to entry: The recovered heat is measured by determining the temperatures and flow rates of heat recovery fluid (water, steam, air or oil, etc.), entering and leaving the thermal energy recovery subsystem at the interface point of the fuel cell power system.

3.1.25

reference condition

values of influence quantities specified for testing the performance of a measuring instrument, which in this document are 288,15 K (15 °C) for temperature and 101,325 kPa for pressure

3.1.26

response time

duration between the instant when the step load change from minimum to rated power or vice versa is initiated and the first instant when the desired value is delivered within a specific tolerance value

3.1.27

shaft work

mechanical energy input from outside the system boundary for accomplishing useful work

3.1.28

shutdown time

duration between the instant when a shutdown action is initiated at rated electric power output and the instant when the shutdown is completed, as specified by the manufacturer

Note 1 to entry: The shutdown operation is classified into types: normal shutdown and emergency shutdown.

[SOURCE: IEC 60050-485:2020, 485-20-04, modified – "a shutdown action is initiated at rated power output" instead of "the load is removed"; "as specified by the manufacturer" added and Note 1 to entry added.]

3.1.29

start-up energy

sum of the electric, thermal, mechanical and chemical (fuel) energy required by a fuel cell power system during the start-up time

[SOURCE: IEC 60050-485:2020, 485-18-05]

3.1.30

start-up time

<for fuel cell power systems that do not require external energy to maintain a storage state> duration required for transitioning from cold state to positive net electrical power output

[SOURCE: IEC 60050-485:2020, 485-20-05, modified – "positive" added.]

3.1.31

start-up time

<for fuel cell power systems that require external power to maintain a storage state> duration required for transitioning from storage state to positive net electrical power output

[SOURCE: IEC 60050-485:2020, 485-20-06, modified – "positive" added.]

3.1.32

steady state

state of a physical system in which the relevant characteristics remain constant with time

[SOURCE: IEC 60050-485:2020, 485-21-05]

3.1.33

storage state

state of a fuel cell power system being non-operational and possibly requiring, under conditions specified by the manufacturer, the input of thermal energy, electric energy or an inert atmosphere, or any combination thereof, in order to prevent deterioration of the components or to energize the control systems, or both

[SOURCE: IEC 60060-485:2020, 485-21-06, modified – "or to energize the control system, or both" added.]

3.1.34

test run

testing phase in which data points required for the computation of test results are recorded

3.1.35

thermal power output

thermal power generated by the fuel cell power system and available for external use

3.1.36

total power input

total consisting of fuel power input, oxidant (air) power input, auxiliary electric power input, shaft work power input and external thermal power input

3.1.37

vibration level

mechanical oscillation level produced by the fuel cell power system during operation

Note 1 to entry: This is a value expressed in decibels (dB) as described in this document.

3.1.38

waste heat

thermal energy output released and not recovered

3.1.39

waste water

excess water that is removed from the fuel cell power system and that does not constitute part of the thermal recovery system

3.1.40**water consumption**

water supplied from outside the system boundary to the fuel cell power system other than the initial fill

3.2 Symbols

The symbols and their meanings used in this document are given in Table 1, with the appropriate units.

Table 1 – Symbols

Symbol	Definition	Unit
c	Specific heat capacity	
c_{HR}	Specific heat capacity of heat recovery fluid	kJ/(kg K)
c_j	Specific heat capacity of pure component j	kJ/(kg K)
E	Energy	
E_{st}	Start-up energy	kJ
E_{elst}	Electric start-up energy	kJ
E_{fst}	Fuel start-up energy	kJ
E_{ast}	Oxidant (air) start-up energy	kJ
E_{Vf}	Energy input of the fuel per unit volume	kJ/m ³
E_{mf}	Energy input of fuel per mole, as given in Table B.2 (worksheet 1)	kJ/mol
E_{mpf}	Pressure energy of the fuel per mole at average pressure p_f	kJ/mol
E_{ma}	Energy input of oxidant (air) per mole	kJ/mol
E_{mpa}	Pressure energy of oxidant (air) per mole	kJ/mol
H	Heating value	
H_{f0}	Heating value of gaseous fuel under reference conditions	kJ/mol
H_{f0j}	Heating value of component j at reference temperature T_0	kJ/mol
H_{fl}	Heating value of liquid fuel at average temperature T_f	kJ/kg
H_m	Molar enthalpy	
H_{mf}	Molar enthalpy of fuel at average temperature T_f	kJ/mol
H_{ma}	Molar enthalpy of oxidant (air) at average temperature T_a	kJ/mol
H_{mf0}	Molar enthalpy of fuel at reference temperature T_0	kJ/mol
H_{ma0}	Molar enthalpy of oxidant (air) at reference temperature T_0	kJ/mol
H_{mtj}	Molar enthalpy of component j at average temperature T_f	kJ/mol
h_m	Specific enthalpy	
h_{min}	Average specific enthalpy of heat transfer fluid (steam, air, etc.) entering the fuel cell power system over the test duration	kJ/kg
h_{mout}	Average specific enthalpy of heat transfer fluid (steam, air, etc.) exiting the fuel cell power system over the test duration	kJ/kg
h_{mwsat0}	Specific enthalpy of saturated water at reference temperature T_0	kJ/kg
h_{mair0}	Specific enthalpy of dry air at reference pressure p_0 and reference temperature T_0	kJ/kg
M_m	Molar mass	
M_{ma}	Molar mass of oxidant (air)	kg/mol
M_{mf}	Molar mass of fuel	kg/mol
m	Mass	
m_{htf}	Mass of heat transfer fluid (steam, air, etc.) into (and out of) the fuel cell power system from the source of external thermal energy over the test duration	kg

Symbol	Definition	Unit
P	Power	
P_{elout}	Average electric power output (including direct current)	kW
P_{elin}	Average auxiliary electric power input to auxiliary machines and equipment from external power source(s) (including direct current)	kW
P_{n}	Average net electric power output	kW
P_{min}	Minimum net electric power output	kW
P_{rated}	Rated net electric power output	kW
P_{in}	Average total power input	kJ/s
P_{fin}	Average gaseous or liquid fuel power input	kJ/s
P_{ain}	Average oxidant (air) power input	kJ/s
P_{wsin}	Average mechanical shaft work power input	kJ/s
P_{HR}	Average recovered thermal power output over the test duration	kJ/s
P_{thin}	Average external thermal power input	kJ/s
p	Pressure	
p_0	Reference pressure	kPa
p_{f}	Average pressure of fuel over the test duration	kPa
p_{a}	Average pressure of oxidant (air) over the test duration	kPa
Q	Thermal energy	
Q_{HR}	Recovered thermal energy over the test duration	kJ
Q_{thin}	Total external thermal energy input to the fuel cell power system over the test duration	kJ
Q_{thst}	Thermal start-up energy	kJ
q_{m}	Mass flow rate	
q_{mw}	Water consumption	kg/s
q_{mf}	Average mass flow rate of fuel	kg/s
q_{ma}	Average mass flow rate of oxidant (air)	kg/s
q_{mHR}	Mass flow rate of heat recovery fluid	kg/s
q_{V}	Volumetric flow rate	
q_{Vf0}	Average volumetric flow rate of fuel under reference conditions	m ³ /s
q_{Va0}	Average volumetric flow rate of oxidant (air) under reference conditions	m ³ /s
q_{Vf}	Average volumetric flow rate of fuel at average temperature T_{f} and average pressure p_{f}	m ³ /s
q_{Va}	Average volumetric flow rate of oxidant (air) at average temperature T_{a} and average pressure p_{a}	m ³ /s
q_{Vpg}	Purge gas flow rate	m ³ /s
q_{VHR}	Volumetric flow rate of heat recovery fluid	m ³ /s
T	Temperature	
T_0	Reference temperature	K
T_{f}	Average temperature of fuel over the test duration	K
T_{a}	Average temperature of oxidant (air) over the test duration	K
T_{HR1}	Temperature of heat recovery fluid output	K
T_{HR2}	Temperature of heat recovery fluid input	K

Symbol	Definition	Unit
t	Time	
Δt_{st}	Start-up time	s
t_{st1}	Start-up initiation time point	
t_{st2}	Start-up completion time point	
Δt_{shut}	Shutdown time	s
t_{shut1}	Shutdown initiation time point	
t_{shut2}	Shutdown completion time point	
t_{up}	Response time required from t_{ini} to $t_{attain-rated}$	s
t_{down}	Response time required from t_{in} to $t_{attain-min}$	s
$t_{attain-rated}$	Time point for the fuel cell power system to attain rated net electric or thermal power output within ± 2 % of rated power	
$t_{attain-min}$	Time point for the fuel cell power system to attain minimum net electric or thermal power output within ± 2 % of rated power	
t_{ini}	Time point when a net electric or thermal power output change is initiated by the user	
t_{dur}	Duration of measurement interval	s
V_m	Molar volume	
V_{m0}	Reference molar volume of ideal gas ($2,364\ 5 \times 10^{-2}$ m ³ /mol) (at reference temperature; 101,325 kPa: $t_0 = 288,15$ K)	m ³ /mol
W_s	Shaft work	
W_{sin}	Total shaft work	kJ
W_{sst}	Shaft work start-up energy	kJ
x	Mass fraction	
x_j	Mass fraction of component j Molar ratio of component j	kg/kg mol/mol
η	Efficiency	
η_{el}	Electrical efficiency	%
η_{th}	Heat recovery efficiency	%
η_{total}	Overall energy efficiency	%
λ	Power factor	
λ	Power factor, the ratio of the active power to the apparent power	
ρ	Density	
ρ_{f0}	Density of fuel under reference conditions	kg/m ³
ρ_{f0j}	Density of component j at reference temperature T_0	kJ/mol
ρ_{fl}	Density of liquid fuel at average temperature T_f	kg/m ³
ρ_{a0}	Density of oxidant (air) under reference conditions	kg/m ³
ρ_{HR}	Density of the heat recovery fluid at measured pressure and temperature	kg/m ³
Φ	Heat rate	
Φ_{WH}	Average waste heat rate	kJ/s
NOTE The main symbols in the fuel cell power system correspond to those in Figure 2.		

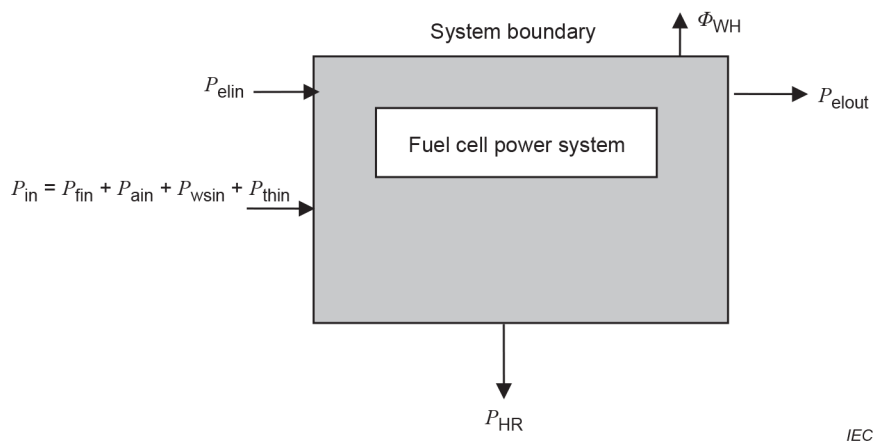


Figure 2 – Symbol diagram for power inputs and outputs

4 Reference conditions

4.1 General

Clause 4 provides the reference conditions for the computation of the test results.

4.2 Temperature and pressure

The reference conditions are specified as follows:

- reference temperature: $T_0 = 288,15 \text{ K (15 °C)}$;
- reference pressure: $p_0 = 101,325 \text{ kPa}$.

4.3 Heating value base

The heating value of fuel is in principle based on the lower heating value (LHV). The heating value of reference gases given in Annex C shall be used. Energy efficiency is expressed as follows:

$$\eta_{el} \text{ or } \eta_{th}; \text{ percent in value (\%)}$$

In the case of LHV, it is not necessary to add the symbol "LHV".

If the higher heating value (HHV) is used, the abbreviation "HHV" shall be added to the value of energy efficiency as follows:

$$\eta_{el} \text{ or } \eta_{th}; \text{ percent in value (\%) (HHV)}$$

5 Items of performance test

The performance assessment of the fuel cell power systems shall be considered from the following points of view:

- a) operation aspects: to test the performance of the system during normal operation or during an operational transient;
- b) environmental aspects: to test how the system affects the environment.