BS EN IEC 62282-3-201:2025

BSI Standards Publication

Fuel cell technologies

Part 3-201: Stationary fuel cell power systems — Performance test methods for small fuel cell power systems

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National foreword

This British Standard is the UK implementation of EN IEC 62282-3-201:2025. It is identical to IEC 62282-3-201:2025. It supersedes BS EN 62282-3-201:2017+A1:2022, which will be withdrawn on 30 November 2028.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

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NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 62282-3-201

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English Version

Fuel cell technologies - Part 3-201: Stationary fuel cell power systems - Performance test methods for small fuel cell power systems (IEC 62282-3-201:2025)

Technologies des piles à combustible - Partie 3-201: Systèmes à piles à combustible stationnaires - Méthodes d'essai des performances pour petits systèmes à piles à combustible (IEC 62282-3-201:2025)

Brennstoffzellentechnologien - Teil 3-201: Stationäre Brennstoffzellen-Energiesysteme - Leistungskennwerteprüfverfahren für kleine Brennstoffzellen-Energiesysteme (IEC 62282-3-201:2025)

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European foreword

The text of document 105/1114/FDIS, future edition 3 of IEC 62282-3-201, prepared by TC 105 "Fuel cell technologies" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62282-3-201:2025.

The following dates are fixed:

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- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2028-11-30

This document supersedes EN 62282-3-201:2017 and all of its amendments and corrigenda (if any).

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The text of the International Standard IEC 62282-3-201:2025 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 61672-1	NOTE	Approved as EN 61672-1
IEC 61672-2	NOTE	Approved as EN 61672-2
IEC 62282-3-200:2025	NOTE	Approved as EN IEC 62282-3-200: —[1] (not modified)
ISO 6974 (series)	NOTE	Approved as EN ISO 6974 (series)
ISO 6975	NOTE	Approved as EN ISO 6975
ISO 7941	NOTE	Approved as EN 27941
ISO 9000	NOTE	Approved as EN ISO 9000
ISO 10523	NOTE	Approved as EN ISO 10523
ISO 11541	NOTE	Approved as EN ISO 11541
ISO 80000 (series)	NOTE	Approved as EN ISO 80000 (series)

[1] Under preparation. Stage at the time of publication: EN IEC 62282-3-200:2025.

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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.cencenelec.eu.

Publication	Year	Title	EN/HD	Year
CISPR 11	-	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN IEC 55011	-
IEC 61000-3-2	-	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	EN IEC 61000-3-2	-
IEC 61000-4-2	-	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test	EN IEC 61000-4-2	-
IEC 61000-4-3	-	Electromagnetic compatibility (EMC) - Part 4-3 : Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test	EN IEC 61000-4-3	-
IEC 61000-4-4	-	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test	EN 61000-4-4	-
IEC 61000-4-5	-	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test	EN 61000-4-5	-
IEC 61000-4-6	-	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields	EN IEC 61000-4-6	-
IEC 61000-4-8	-	Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test	EN 61000-4-8	-
IEC 61000-4-11	-	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase	EN IEC 61000-4-11	-
IEC 61000-6-1	2016	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments	EN IEC 61000-6-1	2019

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

FOREWORD

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IEC 62282-3-201 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 2017 and Amendment 1:2022. This edition constitutes a technical revision.

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

a) revision of Introduction;
b) revision of terms and definitions;
c) revision of Table 1;
d) revision of Figure 1, Figure 2, Figure 3 and Figure 4;
e) revision of measurement instruments (10.2);

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f) revision of minimum required measurement systematic uncertainty (10.4);
g) revision of test conditions (Clause 11);
h) revision of operating process (Clause 12);
i) revision of fuel consumption test (14.2);
j) revision of heat recovery test (14.4);
k) revision of Figure 13 and Figure 14;
l) revision of calculation of results (14.14.4);
m) revision of Annex A and Annex B.

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

Draft	Report on voting
105/1114/FDIS	105/1128/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.

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INTRODUCTION

This part of IEC 62282 provides consistent and repeatable test methods for the electrical, thermal and environmental performance of small stationary fuel cell power systems.

This document limits its scope to small stationary fuel cell power systems (electrical power output below 10 kW, which is typical for residential, small commercial and off-grid applications) and provides test methods specifically designed for them in detail. It is based on the latest edition of IEC 62282-3-200, which generally describes performance test methods that are common to all types of fuel cells.

This document is intended for manufacturers of small stationary fuel cell power systems or those who evaluate the performance of their systems for certification purposes, or both.

Users of this document can selectively execute test items that are suitable for their purposes from those described in this document. This document is not intended to exclude any other methods.

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1 Scope

This part of IEC 62282 provides test methods for the electrical, thermal, and environmental performance of small stationary fuel cell power systems that meet the following criteria:

- output: rated electric power output of less than 10 kW;
- output mode: grid-connected/independent operation or stand-alone operation with single-phase AC output or 3-phase AC output not exceeding 1 000 V, or DC output not exceeding 1 500 V;

  NOTE The limit of 1 000 V for alternating current comes from the definition for "low voltage" given in IEC 60050-601:1985, 601-01-26.
- operating pressure: maximum allowable working pressure of 0,1 MPa (gauge) for the fuel and oxidant passages;
- fuel: gaseous fuel (natural gas, liquefied petroleum gas, propane, butane, hydrogen, etc.) or liquid fuel (kerosene, methanol, etc.);
- oxidant: air.

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

This document provides test methods to be carried out under laboratory conditions.

This document covers fuel cell power systems whose primary purpose is the production of electric power and whose secondary purpose can be the utilization of heat. Accordingly, fuel cell power systems for which the use of heat is primary, and the use of electric power is secondary are outside the scope of this document.

All systems with integrated batteries are covered by this document. This includes systems where batteries are recharged internally or recharged from an external source.

This document does not cover additional auxiliary heat generators that produce thermal energy.

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.

CISPR 11, *Industrial, scientific, and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement*

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

IEC 61000-4-2, *Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test*

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IEC 61000-4-5, *Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments*

3 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
background noise level
sound pressure level of ambient noise at the measurement point

Note 1 to entry: This measurement is taken as described in 15.2 with the fuel cell power system in the cold state.

3.2
battery
electrochemical energy storage device that provides energy input to auxiliary machines and equipment necessary to operate the fuel cell power system and/or provides electric energy output

Note 1 to entry: Back-up batteries for control software memory and similar applications are not included.

3.3
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 considered.

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

3.4
degradation rate
reduction of the electrical efficiency of a stationary fuel cell power system per time of operation

Note 1 to entry: The degradation rate is expressed in efficiency per cent points per time (%/h).

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3.5
discharge water
water that is discharged from the fuel cell power system including waste water and condensate

Note 1 to entry: Discharge water does not constitute part of a thermal recovery system.

3.6
electrical efficiency
ratio of the average net electric power output produced by a fuel cell power system to the average fuel 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: Only the fuel energy is considered as input power to small fuel cell power systems.

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

3.7
electric energy input
integrated value of electric power input at the electric input terminal

3.8
electric energy output
integrated value of electric power output at the electric output terminal

3.9
electric power input
electric power input at the electric input terminal of the fuel cell power system

3.10
electric power output
electric power output at the electric output terminal of the fuel cell power system

3.11
fuel cell power system
generator system that uses one or more fuel cell modules to generate electric power and heat

[SOURCE: IEC 60050-485:2020, 485-09-01]

3.12
fuel energy input
amount of chemical energy which is supplied to the fuel cell power system by the fuel

3.13
fuel input
amount of natural gas, hydrogen, methanol, liquid petroleum gas, propane, butane, or other material containing chemical energy entering the fuel cell power system while it is working at the specified operating conditions

3.14
fuel power input
fuel energy input per unit of time

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3.15
heat recovery efficiency
ratio of the average recovered thermal power output of a fuel cell power system to the average fuel 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: Only the fuel energy is considered as input power to small fuel cell power systems.

[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, new Note 1 to entry and Note 2 to entry added.]

3.16
heat recovery fluid
fluid circulating between the fuel cell power system and a heat sink for recovering the thermal energy output

3.17
inert purge gas
inert gas or dilution gas, not containing chemical energy, supplied to the fuel cell power system during specific conditions to make it ready for operation or shutdown

Note 1 to entry: Dilution gas containing chemical energy shall be considered as fuel.

3.18
integrated fuel input
volume or mass of fuel consumed by the fuel cell power system under specified operating conditions

3.19
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 2) to be assessed should be determined by agreement between the parties.

[SOURCE: IEC 60050-485:2020, 485-09-12, modified – Note 2 to entry deleted.]

3.20
mass concentration
concentration of mass of exhaust gas component per unit of volume

3.21
mass discharge rate
mass of discharged exhaust gas component per unit of time

3.22
minimum electric power output
minimum net power output, at which a fuel cell power system is able to operate continuously at a steady state

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3.23
net electric power output
power generated by the fuel cell power system and available for external use

Note 1 to entry: The net electric power output can be negative during start-up, shutdown and storage state, which means actually an electric power input during these phases / state, to be provided externally and not generated by the fuel cell power system.

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

3.24
noise level
sound pressure level produced by the fuel cell power system

Note 1 to entry: The noise level is expressed as decibels (dB) and measured as described in 15.2.

3.25
operation cycle
complete sequence of successive operation phases of a fuel cell power system comprising start-up, ramp-up, rated operation and shutdown

3.26
operation cycle electrical efficiency
ratio of the net electric energy output of a fuel cell power system to the fuel energy fed to the same fuel cell power system during a complete operation cycle comprising start-up, ramp-up, rated operation and shutdown

3.27
overall energy efficiency
ratio of total usable power output (net electric power and recovered thermal power) to the average total power input supplied to the fuel cell power system

Note 1 to entry: For determining the total power input to small fuel cell power systems, power inputs other than fuel power input are neglected as insignificant

[SOURCE: IEC 60050-485:2020, 485-10-05, modified – alternative expression "or total thermal efficiency" deleted; "power output" instead of "energy flow"; "thermal power" instead of "heat flow"; "average total power input" instead of "total enthalpy flow"; Note 1 to entry changed.]

3.28
pre-generation state
state of a fuel cell power system at 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 electric active power output

[SOURCE: IEC 60050-485:2020, 485-21-04, modified – "active" added.]

3.29
ramp-up energy
electric and/or chemical (fuel) energy required for transitioning from positive net electric power output after start-up to rated net electric power output

3.30
ramp-up time
duration required for transitioning from positive net electric power output after start-up to rated net electric power output

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3.31
rated electric power output
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 – "electric" and "output" added to the term, Note 1 to entry deleted.]

3.32
recovered heat
thermal energy that has been recovered for useful purpose

3.33
recovered thermal power
recovered heat per unit of time

Note 1 to entry: The recovered thermal power is measured by determining the temperatures and flow rates of the 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.

3.34
shutdown energy
sum of electric and/or chemical (fuel) energy required during the shutdown time

3.35
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 electric power output" instead of "the load is removed"; "Note 1 to entry" added.]

3.36
start-up energy
<fuel cell power systems without battery> sum of electric, thermal, mechanical and chemical (fuel) energy required by a fuel cell power system for transitioning from cold state or storage state to positive net electric power output

Note 1 to entry: The start-up process of fuel cell power systems without battery is shown in Figure 7.

[SOURCE: IEC 60050-485:2020, 485-18-05, modified – addition of domain, "for transitioning from cold state or storage state to positive net electric power output" instead of "during the start -up time" and Note 1 to entry added.]

3.37
start-up energy

<fuel cell power systems with battery> sum of electric, thermal, mechanical and chemical (fuel) energy required by a fuel cell power system for recharging the battery, which is discharged to supply rated electric power output during start-up time, to a known nominal state of charge

Note 1 to entry: The start-up process of fuel cell power systems with battery is shown in Figure 8.

[SOURCE: IEC 60050-485:2020, 485-18-05, modified – addition of domain "for recharging the battery, which is discharged to supply rated electric power output during start-up time, to a known nominal state of chargefor transitioning from cold state or storage state to positive net electric power output" instead of during the start -up time" and Note 1 to entry added.]

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3.38
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 electric power output

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

3.39
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 electric power output

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

3.40
stationary fuel cell power system
fuel cell power system that is connected and fixed in place

[SOURCE: IEC 60050-485:2020, 485-09-24]

3.41
steady state
state of a physical system in which the relevant characteristics remain constant with time

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

3.42
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 energize the control systems and other components, or both, and is ready for start-up

[SOURCE: IEC 60050-485:2020, 485-21-06, modified – "or energize the control systems and other components, or both, and is ready for start-up" added.]

3.43
test run
testing phase in which data points required for the computation of test results are recorded

3.44
thermal storage unit
unit that stores heat recovered from the fuel cell power system in the thermal storage medium and supplies the heat with heat carrier externally as needed

Note 1 to entry: It is composed of a thermal storage tank, a heat exchanger and a heat carrier supply system.

Note 2 to entry: A typical thermal storage medium is water.

3.45
test duration
duration of the complete test for the estimation of the electric and heat recovery efficiency up to ten years of operation, comprising a specific number of test runs

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4 Symbols

The symbols and their meanings used in this part of IEC 62282 are given in Table 1 for electrical/thermal performance and Table 2 for environmental performance, with the appropriate units.

Table 1 – Symbols and their meanings for electric and thermal performance

Symbol	Definition	Unit
$\boldsymbol{c}$	**Specific heat capacity**	
c_{HR}	Specific heat capacity of heat recovery fluid (at constant pressure)	kJ/(kg·K)
$\boldsymbol{E}$	**Energy**	
$E_{m\mathrm{f}}$	Energy input of gaseous fuel per unit mass	kJ/kg
$E_{V\mathrm{f}}$	Energy input of the fuel per unit volume	kJ/m^3
E_{fin}	Fuel energy input	kJ
E_{finstbat}	Fuel energy input required during start-up time for system with battery	kJ
E_{finst}	Fuel energy input required during start-up time	kJ
E_{finramp}	Fuel energy input required during ramp-up time	kJ
E_{finshut}	Fuel energy input required during shutdown time	kJ
E_{fincyc}	Fuel energy input required for an operating cycle from start-up, over ramp-up and rated operation to shutdown	kJ
$\boldsymbol{H}$	**Heating value**	
H_{f0}	Heating value of fuel on a molar basis under reference conditions	kJ/mol
$H_{\mathrm{f0}j}$	Heating value of component j at reference temperature T_0	kJ/mol
H_{fl}	Heating value of liquid fuel	kJ/kg
$\boldsymbol{M}$	**Molar mass**	
M_{f}	Molar mass of fuel	kg/mol
$\boldsymbol{m}$	**Mass**	
m_{f}	Fuel mass measured over the test duration	kg
m_{HR}	Heat recovery fluid mass	kg
$\boldsymbol{P}$, $\mathrm{d}\boldsymbol{P}$	**Power, power change rate**	
P_{n}	Average net electric power output	kW
P_{rated}	Rated electric power output	kW
P_{min}	Minimum electric power output	kW
P_{d}	Electric power output change range between P_{rated} and P_{min}	kW
P_{instore}	Average electric power input in storage state	kW
P_{HR}	Average recovered thermal power	kJ/s
P_{fin}	Average fuel power input	kJ/s
$\mathrm{d}P_{\mathrm{down}}$	Decrease rate of electric power output	kW/s
$\mathrm{d}P_{\mathrm{up}}$	Increase rate of electric power output	kW/s
$\boldsymbol{p}$	**Pressure**	
p_0	Reference pressure (101,325 kPa(abs))	kPa(abs)
p_{f}	Average fuel pressure	kPa(abs)

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Symbol	Definition	Unit
RH	**Relative humidity**	%
q_m	**Mass flow rate**	
q_{mf}	Average mass flow rate of fuel	kg/s
q_{mHR}	Average mass flow rate of heat recovery fluid	kg/s
q_V	**Volumetric flow rate**	
q_{Vf}	Average volumetric flow rate of fuel under the test conditions	m^3/s
q_{Vf0}	Average volumetric flow rate of fuel under reference conditions	m^3/s
q_{VHR}	Average volumetric flow rate of heat recovery fluid	m^3/s
T	**Temperature**	
T_0	Reference temperature (288,15 K)	K
T_f	Average fuel temperature	K
T_{HR1}	Average temperature of heat recovery fluid output	K
T_{HR2}	Average temperature of heat recovery fluid input	K
T_s	Standard temperature (273,15 K)	K
ΔT	Temperature difference between heat recovery fluid output and input	K
t	**Time**	
Δt	Test duration	s, h
Δt_a	Number of hours between point s and point a	h
Δt_{st}	Start-up time	s
Δt_{stbat}	Duration from the start-up initiation to battery recharge completion	s
t_{st1}	Start-up initiation time point	
t_{st2}	Start-up completion time point	
t_{st3bat}	Battery recharge completion time point	
Δt_{shut}	Shutdown time	s
t_{shut1}	Shutdown initiation time point	
t_{shut2}	Shutdown completion time point	
Δt_{lcdown}	Duration of the decrease in electric power output from t_{lc1} to t_{lc2}	s
Δt_{lcup}	Duration of the increase in electric power output from t_{lc3} to t_{lc4}	s
t_{lc1}	Start time point of electric power output decreasing action	
t_{lc2}	Time point when the electric power output reaches the minimum electric power output within ±2 % of rated electric power output	
t_{lc3}	Start time point of electric power output increasing action	
t_{lc4}	Time point when the electric power output reaches the rated electric power output within ±2 % of rated electric power output	
t_{rated}	Duration of the rated power output phase of an operation cycle from start-up, over ramp-up and rated power operation to shutdown	s
Δt_{ramp}	Ramp-up time	s
t_{ramp1}	Ramp-up start time point	
t_{ramp2}	Ramp-up completion time point	

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Symbol	Definition	Unit
V	**Volume**	
V_f	Fuel volume measured over the test duration	m^3
V_{HR}	Heat recovery fluid volume	m^3
V_m	**Molar volume**	
V_m	Reference molar volume of ideal gas (2,364 5 × 10^{-2} m^3/mol at reference temperature T_0 = 288,15 K or 2,241 4 × 10^{-2} m^3/mol at standard temperature T_s = 273,15 K, both at reference pressure p_0 = 101,325 kPa)	m^3/mol
W	**Electric energy**	
W_{out}	Electric energy output	kW·h
W_{outbat}	Electric energy output over the duration from the start-up initiation time point, t_{st1} to the battery recharge completion time point, t_{st3bat}	kW·h
W_{in}	Electric energy input	kW·h
W_{inbat}	Electric energy input over the duration from the start-up initiation time point, t_{st1} to the battery recharge completion time point, t_{st3bat}	kW·h
W_{inst}	Electric energy input during start-up time	kW·h
$W_{instbat}$	Electric energy required over the duration from the start-up initiation time point, t_{st1} to the battery recharge completion time point, t_{st3bat}	kW·h
W_{inshut}	Electric energy input during shutdown time	kW·h
$W_{instore}$	Electric energy input at storage state	kW·h
$W_{outramp}$	Electric energy output during ramp-up time	kW·h
W_{outcyc}	Net electric energy output during an operating cycle from start-up, over ramp-up and rated operation to shutdown	kW·h
x	**Molar ratio**	
x_j	Molar ratio of component j	
η	**Efficiency**	
η_{el}	Electrical efficiency	%
η_{th}	Heat recovery efficiency	%
η_{total}	Overall energy efficiency	%
η_{cyc}	Operation cycle electrical efficiency	%
$\eta_{el,est,av}$	Estimated average electrical efficiency during one year of operation	%
$\eta_{el,est}(k)$	Estimated electrical efficiency at the end of year k	%
$\eta_{el,init}$	Calculated value of the linear regression of the electrical efficiency at the time of point a	%
$\Delta\eta_{el}$	Approximated degradation rate of the electrical efficiency	%/h
$\eta_{th,est}(k)$	Estimated heat recovery efficiency at the end of year k	%
ρ	**Density**	
ρ_f	Density of the liquid fuel	kg/m^3
ρ_{HR}	Density of heat recovery fluid at T_{HR1}	kg/m^3
NOTE 1 The main symbols in the fuel cell power system are found in Figure 1. NOTE 2 THC is the total hydrocarbon.		

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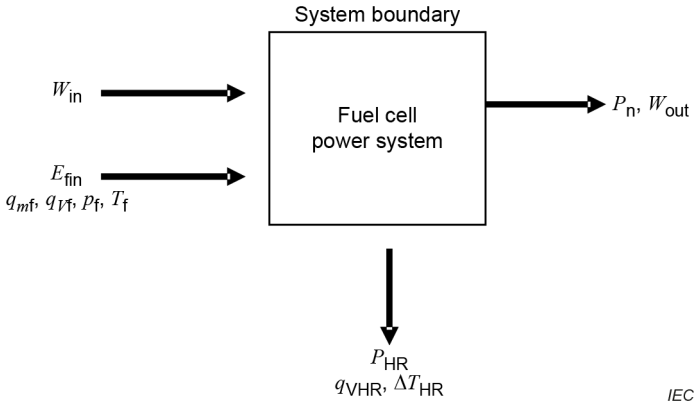

Figure 1 – Symbol diagram

Table 2 – Additional symbols and their meanings for environmental performance

Symbol	Definition	Unit
M_r	**Relative molecular mass**	
$M_{r,f}$	Compositional relative molecular mass of the fuel	
$M_r(CO_2)$	Relative molecular mass of CO_2 ($M_r(CO_2) \approx 44{,}01$)	
$M_r(CO)$	Relative molecular mass of CO ($M_r(CO) \approx 28{,}01$)	
$M_r(THC)$	Compositional relative molecular mass of THC	
$M_r(NO_x)$	Relative molecular mass of NO_x when the entire amount of NO_x is assumed to be NO_2 ($M_r(NO_x) \approx 46{,}01$)	
$M_r(SO_2)$	Relative molecular mass of SO_2 ($M_r(SO_2) \approx 64{,}06$)	
q_m	**Mass discharge rate**	
$q_{m,ex}(CO_2)$	CO_2 mass discharge rate by the exhaust	g/h
$q_{m,ex}(CO)$	CO mass discharge rate by the exhaust	g/h
$q_{m,ex}(THC)$	THC mass discharge rate by the exhaust	g/h
$q_{m,ex}(NO_x)$	NO_x mass discharge rate by the exhaust	g/h
$q_{m,ex}(SO_2)$	SO_2 mass discharge rate by the exhaust	g/h
V	**Volume ratio**	
$V_{ex,th,dr,V}$	Theoretical ratio of dry exhaust gas volume per volume of gaseous input fuel	m^3/m^3
$V_{ex,th,dr,m}$	Theoretical ratio of dry exhaust gas volume per mass of liquid input fuel	m^3/kg
$V_f(H_2)$	Volume ratio of H_2 in unit volume per volume of input fuel	m^3/m^3
$V_f(CO)$	Volume ratio of CO in unit volume per volume of input fuel	m^3/m^3
$V_f(CO_2)$	Volume ratio of CO_2 in unit volume per volume of input fuel	m^3/m^3
$V_f(N_2)$	Volume ratio of N_2 in unit volume per volume of input fuel	m^3/m^3
$V_f(CH_4)$	Volume ratio of CH_4 in unit volume per volume of input fuel	m^3/m^3
$V_f(C_2H_6)$	Volume ratio of C_2H_6 in unit volume per volume of input fuel	m^3/m^3
$V_f(C_3H_8)$	Volume ratio of C_3H_8 in unit volume per volume of input fuel	m^3/m^3
$V_f(C_4H_{10})$	Volume ratio of C_4H_{10} in unit volume per volume of input fuel	m^3/m^3
$V_f(C_5H_{12})$	Volume ratio of C_5H_{12} in unit volume per volume of input fuel	m^3/m^3

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Symbol	Definition	Unit
w	**Mass fraction**	
w(C)	Mass fraction of the element C in unit mass of input fuel	kg/kg
w(H)	Mass fraction of the element H in unit mass of input fuel	kg/kg
w(S)	Mass fraction of the element S in unit mass of input fuel	kg/kg
w(N)	Mass fraction of the element N in unit mass of input fuel	kg/kg
w(O)	Mass fraction of the element O in unit mass of input fuel	kg/kg
α	**Hydrogen to carbon atom ratio**	
α_f	Hydrogen to carbon atom ratio of fuel	
α(THC)	Hydrogen to carbon atom ratio of THC in exhaust gas	
γ	**Mass concentration**	
γ_{ex}(CO)	CO mass concentration in dry exhaust gas	mg/m^3
γ_{ex}(H_2)	H_2 mass concentration in dry exhaust gas	mg/m^3
γ_{ex}(THC)	THC mass concentration in dry exhaust gas	mg/m^3
γ_{ex}(NO_x)	NO_x mass concentration in dry exhaust gas	mg/m^3
γ_{ex}(SO_2)	SO_2 mass concentration in dry exhaust gas	mg/m^3
ε	**Emission**	
ε(CO)	Mass of CO emission per unit energy of fuel input	mg/kW·h
ε(THC)	Mass of THC emission per unit energy of fuel input	mg/kW·h
ε(NO_x)	Mass of NO_x emission per unit energy of fuel input	mg/kW·h
ε(SO_2)	Mass of SO_2 emission per unit energy of fuel input	mg/kW·h
ρ	**Density**	
ρ(CO)	CO density	kg/m^3
ρ(H_2)	H_2 density	kg/m^3
ρ(NO_2)	NO_2 density	kg/m^3
ρ(SO_2)	SO_2 density	kg/m^3
φ	**Volume fraction**	
$\varphi_{B,corr}$	Corrected volume fraction of the component B	ml/m^3, vol %
$\varphi_{B,meas}$	Measured volume fraction of the component B	ml/m^3, vol %
φ_{at}(O_2)	Measured value of O_2 volume fraction in atmosphere at air inlet in dry state (in case of fresh air, φ_{at}(O_2) ≈ 21 %)	vol %
φ_{ex}(O_2)	Measured O_2 volume fraction in dry exhaust gas	vol %
$\varphi_{ex,corr}$(CO_2)	Corrected CO_2 volume fraction in dry exhaust gas	vol %
$\varphi_{ex,corr}$(CO)	Corrected CO volume fraction in dry exhaust gas	ml/m^3
$\varphi_{ex,corr}$(H_2)	Corrected H_2 volume fraction in dry exhaust gas	ml/m^3
$\varphi_{ex,corr}$(THC)	Corrected THC volume fraction in dry exhaust gas (carbon equivalent)	ml/m^3
$\varphi_{ex,corr}$(NO_x)	Corrected NO_x volume fraction in dry exhaust gas	ml/m^3
$\varphi_{ex,corr}$(SO_2)	Corrected SO_2 volume fraction in dry exhaust gas	ml/m^3

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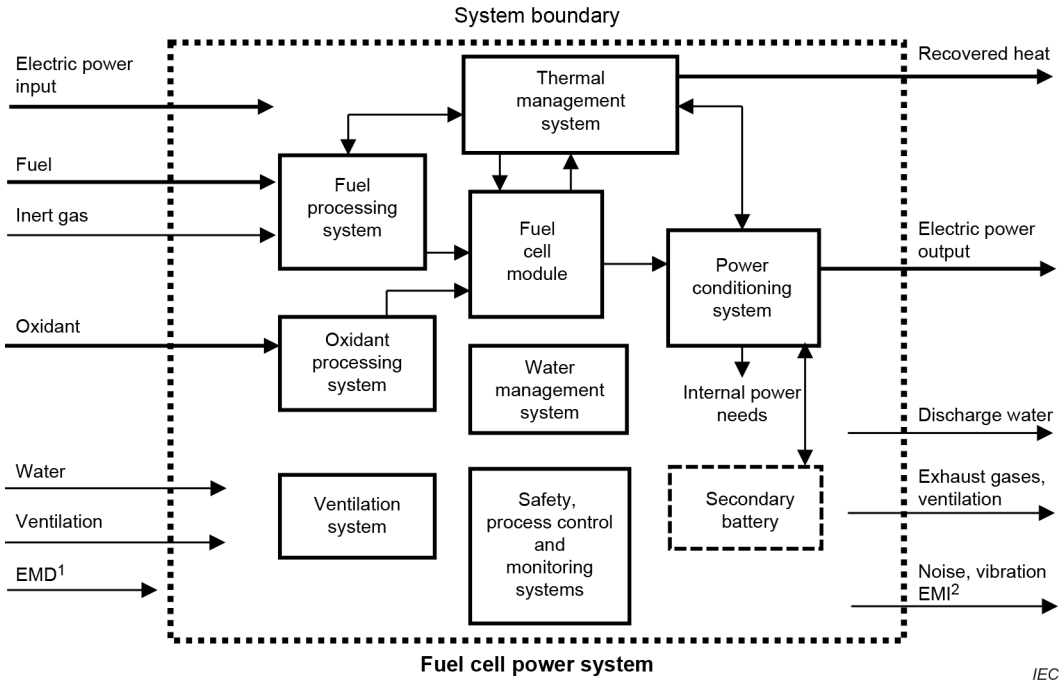
5 Configuration of small stationary fuel cell power system

Figure 2 illustrates the general configuration of small stationary fuel cell power systems subject to this document and shows the system boundary and physical quantities, fluids and environmental factors entering and leaving the fuel cell power system.



Key

1 EMD electromagnetic disturbance

2 EMI electromagnetic interference

NOTE Figure 2 displays only the major interconnections between the subsystems.

Figure 2 – General configuration of small stationary fuel cell power system

6 Reference conditions

The reference conditions are specified as follows:

– reference temperature: T_0 = 288,15 K (15 °C);

– reference pressure: p_0 = 101,325 kPa (abs).

7 Heating value base

The heating value of fuel is based on the lower heating value (LHV) in principle.

In cases where LHV is applied for the calculation of energy efficiency, it is not necessary to add the symbol "LHV", as shown below:

$$\eta_{el},\ \eta_{th},\ \text{or}\ \eta_{total} = XX\ \%$$

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

$$\eta_{el},\ \eta_{th},\ or\ \eta_{total} = XX\ \%\ (HHV)$$

NOTE Heating values of fuels for both LHV and HHV are given in Table A.1.

8 Test preparation

8.1 General

Clause 8 describes typical items that shall be considered prior to the implementation of a test. For each test, an effort shall be made to minimize uncertainty by selecting high-precision instruments and planning the tests carefully with attention to detail. Detailed test plans shall be prepared by the parties to the test using this document as their basis. A written test plan shall be prepared.

The following items shall be considered for the test plan:

a) objective;
b) test specifications;
c) test personnel qualifications;
d) quality assurance standards (e.g. ISO 9000 or other equivalent standards);
e) target uncertainty;
f) identification of measurement instruments (refer to Clause 10);
g) estimated range of test parameters;
h) data acquisition plan.

8.2 Uncertainty analysis

An uncertainty analysis should be performed on the three test items below to indicate the reliability of the test results and to comply with customer requests. The following test results should be analysed to determine the absolute and relative uncertainty. A test should be planned so that the reliability of the results can be evaluated for the following:

– electrical efficiency;
– heat recovery efficiency;
– overall energy efficiency.

Guidance on uncertainty analysis is given in the ISO/IEC Guide 98-1 and ISO/IEC Guide 98-3.

NOTE See also IEC 62282-3-200:2025, Annex A.

8.3 Data acquisition plan

In order to meet the target uncertainty, proper duration and frequency of readings shall be defined and suitable data recording equipment shall be prepared before the performance test.

Automatic data acquisition using a personal computer or similar is preferable.

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9 Test set-up

Figure 3 and Figure 4 illustrate examples of the test set-up that is required to conduct small stationary fuel cell power system testing with gaseous fuel described in this document. In Figure 3, an electric load and a thermal load are connected to a fuel cell power system. Figure 3 illustrates the measurement of electric characteristics and heat recovery characteristics of the system. A thermal storage unit, which stores heat recovered from the fuel cell power system in the thermal storage medium can be used as the thermal load. In Figure 4, only an electric load is connected to the fuel cell power system. Figure 4 illustrates the measurement of electric characteristics of the system.

For the electric demand-following test (14.14), the electric load shall be capable of applying or simulating an electric load profile to the system. It can be replaced or upgraded by a device, which is capable of doing this. Alternatively, the tested small stationary fuel cell power system can be equipped with means for setting and operating a load profile.

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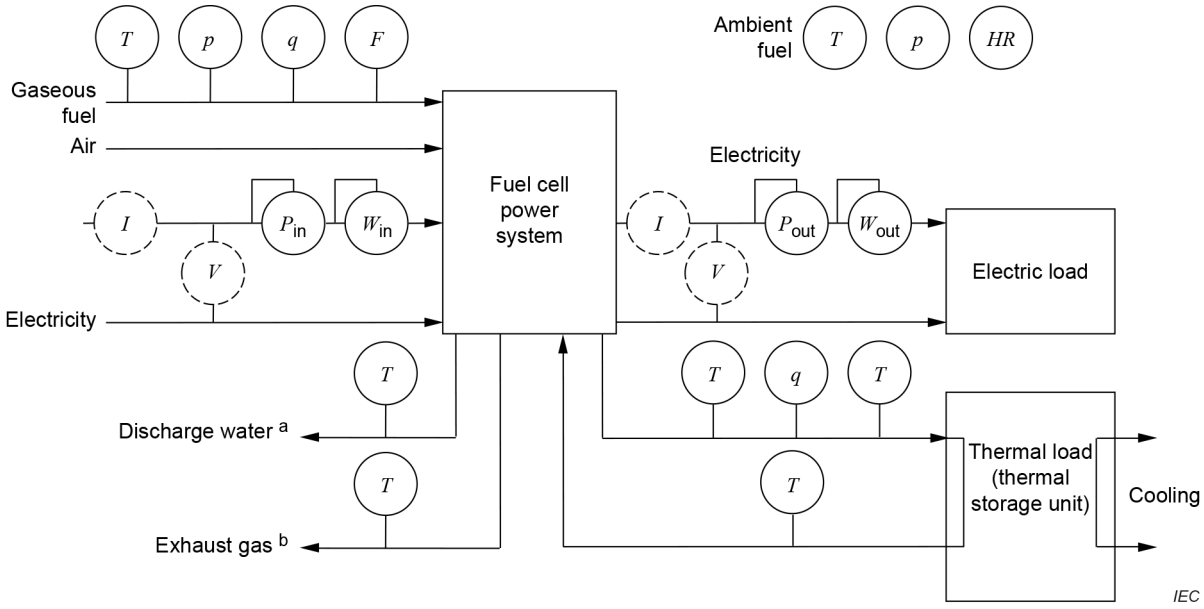

Key

(I) ammeter (optional)

(V) voltmeter (optional)

(T) thermometer

(p) pressure gauge

(q) flowmeter

(F) integrating flowmeter

(P) electric power meter

(W) electric energy meter

(RH) relative humidity meter

a to collecting device to measure volume (or mass), pH, BOD (biochemical oxygen demand), COD (chemical oxygen demand)

b to collecting device to analyse components

Measurement of current and voltage are optional and may replace power/energy measurements.

Measurement of electric power and energy may be performed by one single measurement device.

Measurement of flow and integrated flow may be performed by one single measurement device.

Figure 3 – Test set-up for small stationary fuel cell power system fed with gaseous fuel which supplies electricity and useful heat

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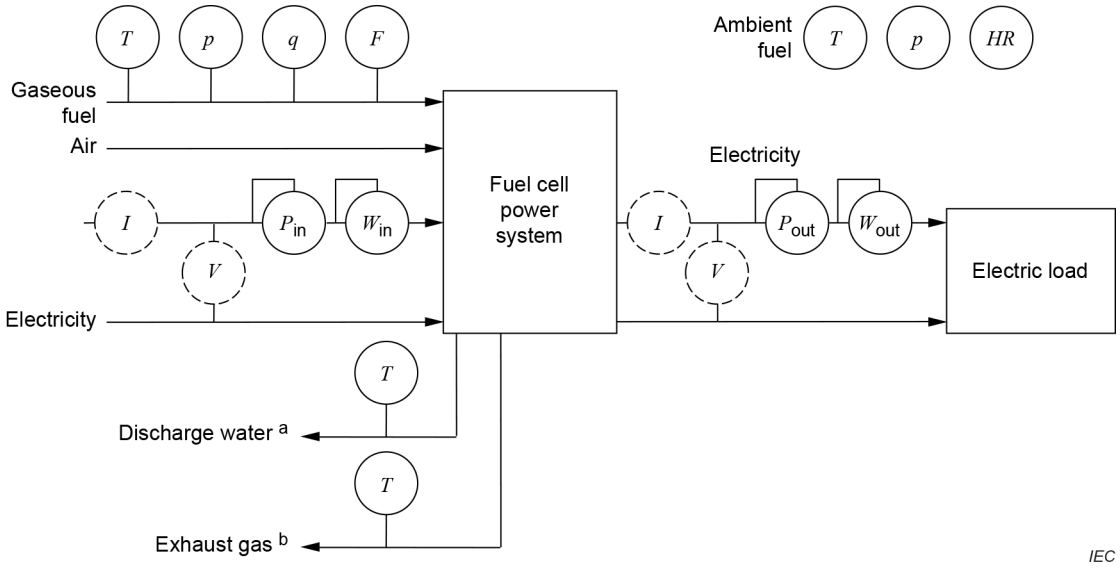

Key

See key for Figure 3.

Measurement of current and voltage are optional and may replace power/energy measurements.

Measurement of electric power and energy may be performed by one single measurement device.

Figure 4 – Test set-up for small stationary fuel cell power system fed with gaseous fuel which supplies only electricity

10 Instruments and measurement methods

10.1 General

Measurement instruments and measurement methods shall conform to the relevant international standards. They shall be selected to meet the measurement range specified by the manufacturer and the required accuracy of measurements.

10.2 Measurement instruments

Measurement instruments are listed according to their intended use:

a) apparatus for measuring the electric power output, electric power input, electric energy input, and electric energy output:
   – electric power meters, electric energy meters, voltmeters, ammeters;
   – for systems that include batteries, a high-speed voltage recorder such as an oscilloscope is required for measuring the increase rate of electric power because the rate is extremely rapid in general (in the order of milliseconds).

b) apparatus for measuring fuel input:
   – flowmeters, integrating flowmeters, scales, pressure sensors, temperature sensors;

c) apparatus for measuring fuel composition:
   – gas chromatographs, mass spectrometers, absorption spectrometers;

d) apparatus for measuring the thermal energy output (only in cases of utilization of the heat):
   – flowmeters, integrating flowmeters, temperature sensors;

e) apparatus for measuring ambient conditions:
   – barometers, hygrometers, and temperature sensors;

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f) apparatus for measuring the noise level:

- sound level meters as specified in IEC 61672-1 or other measuring instruments of equivalent or better accuracy.

  The settings of the measuring instruments are as follows:

- frequency-weighted characteristic: A (see IEC 61672-1);
- time-weighted characteristic: S (see IEC 61672-1);
- unit: dB (for characteristic A, the display of the frequency-weighted characteristic may be omitted);

g) apparatus for measuring volume fractions (concentrations) of the exhaust gas components:

- oxygen analyser (e.g. based on paramagnetic, electrochemical or zirconium oxide sensors);
- carbon dioxide analyser (e.g. gas chromatography–mass spectrometry (GC-MS) or based on infrared absorption sensor);
- carbon monoxide analyser (e.g. based on nondispersive infrared or electrochemical sensor);
- nitrogen oxide analyser (e.g. based on nondispersive infrared or electrochemical sensor);
- sulfur oxide analyser (e.g. Fourier-transform infrared spectroscopy (FTIR) or based on electrochemical sensor);
- THC analyser (e.g. a flame ionizer detector (FID));
- hydrogen analyser (e.g. semiconductor-type gas sensor, catalytic combustion-type gas sensor)

h) apparatus for determining the discharge water:

- graduated cylinder (for volume measurement), temperature sensor, pH meters, biochemical oxygen demand (BOD) probes, chemical oxygen demand (COD) probes.

10.3 Measurement points

Measurement points for different parameters are described below.

a) Gaseous fuel flow rate:

place a flowmeter for fuel on the fuel supply line to the fuel cell power system to measure the fuel flow rate.

b) Gaseous integrated fuel input:

place an integrating flowmeter for fuel on the fuel supply line to the fuel cell power system to measure the fuel input. The integrating flowmeter can incorporate a flowmeter that measures the fuel flow rate.

c) Liquid fuel input mass:

place scales under the fuel tank or the entire system, including the fuel tank, to measure the mass of fuel.

d) Fuel temperature:

connect a thermometer immediately downstream of the fuel flowmeter.

e) Fuel pressure:

place a pressure meter immediately downstream of the fuel flowmeter to measure the gauge pressure of fuel.

f) Electric power output:

connect an electric power meter to the electric power output terminal of the fuel cell power system and close to the system boundary.

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