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

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 62282-3-201 ED3	
DATE OF CIRCULATION: 2023-02-24	CLOSING DATE FOR COMMENTS: 2023-05-19
SUPERSEDES DOCUMENTS: 105/918/RR	

IEC TC 105 : FUEL CELL TECHNOLOGIES	
SECRETARIAT: Germany	SECRETARY: Mr David Urmann
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☒ QUALITY ASSURANCE ☐ SAFETY	

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- any relevant patent rights of which they are aware and to provide supporting documentation,
- any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "in some countries" clauses. See AC/22/2007.

TITLE:

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

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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, **Amendment 1:2022**. This edition constitutes a technical revision.

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

- a)
- a)

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

Draft	Report on voting
105/XXX/FDIS	105/XXX/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.

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,
- replaced by a revised edition, or
- amended.

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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) and provides test methods specifically designed for them in detail. It is based on 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 and/or those who evaluate the performance of their systems for certification purposes.

Users of this document may 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.

FUEL CELL TECHNOLOGIES –

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

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 less than 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 covers fuel cell power systems whose primary purpose is the production of electric power and whose secondary purpose may 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 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*

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*

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

IEC 62282-3-200:2015, *Fuel cell technologies – Part 3-200: Stationary fuel cell power systems – Performance test methods*

3 Terms and definitions

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

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

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

3.1

noise level

sound pressure level produced by the fuel cell power system

Note 1 to entry: Expressed as decibels (dB) and measured as described in 15.2.

3.2

background noise level

sound pressure level of ambient noise at the measurement point

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

3.3

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.

3.4

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.

95 Note 1 to entry: Power input to a control device for monitoring the fuel cell power system during cold state is not
96 considered.

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

99 **3.5**

100 **mass discharge rate**

101 mass of discharged exhaust gas component per unit of time

102 **3.6**

103 **discharge water**

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

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

106 **3.7**

107 **electrical efficiency**

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

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

111 [SOURCE: IEC 60050-485:2020, 485-10-02,, modified — “electrical” instead of “electric” in the
112 term; “average net electric power output” instead of “net electric power”; “average fuel power
113 input” instead of “total enthalpy flow”.]

114 **3.8**

115 **electric energy input**

116 integrated value of electric power input at the electric input terminal

117 **3.9**

118 **electric energy output**

119 integrated value of electric power output at the electric output terminal

120 **3.10**

121 **electric power input**

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

123 **3.11**

124 **electric power output**

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

126 **3.12**

127 **fuel cell power system**

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

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

130 **3.13**

131 **fuel energy input**

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

133 **3.14**

134 **fuel input**

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

3.15**fuel power input**

fuel energy input per unit of time

3.16**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.]

3.17**heat recovery fluid**

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

3.18**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.

3.19**integrated fuel input**

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

3.20**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.]

3.21**mass concentration**

concentration of mass of exhaust gas component per unit of volume

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

3.23**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 term, Notes 1 and 2 to entry deleted.]

3.24**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.]

3.25**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

[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 deleted.]

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

3.31**recovered heat**

thermal energy that has been recovered for useful purpose

Note 1 to entry: The recovered heat 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.

3.32**recovered thermal power**

recovered heat per unit of time

3.33**shutdown energy**

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

3.34**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.]

3.35**start-up energy**

a) <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; and

b) <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

[SOURCE: IEC 60050-485:2020, 485-18-05, modified with addition of domain — case b) added, “for transitioning from cold state or storage state to positive net electric power output” instead of “during the start -up time”.]

3.36**start-up time**

a) 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; and

b) 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, 485-20-05 and 485-20-06, modified — “positive” added]

3.37**stationary fuel cell power system**

fuel cell power system that is connected and fixed in place

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

3.38**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 and/or energize the control systems and other components, and is ready for start-up

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

3.39**test run**

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

3.40**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.

3.41**waste heat**

thermal energy released and not recovered

3.42**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

3.43**degradation rate**

reduction of the electric 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).

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

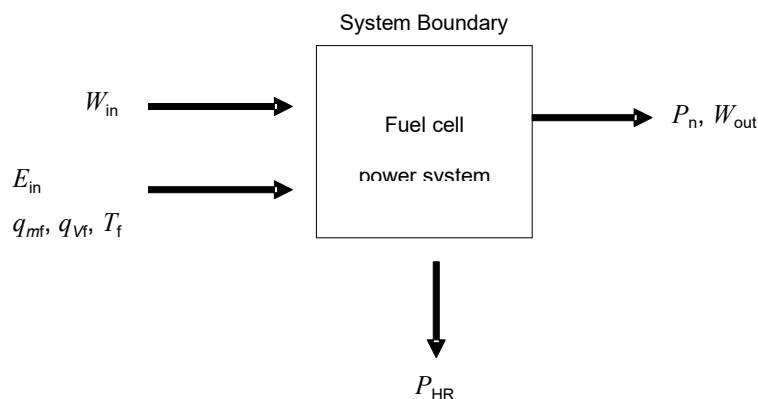
Symbol	Definition	Unit
c	Specific heat	
c_{HR}	Specific heat capacity of heat recovery fluid	kJ/(kg·K)
E	Energy	
E_{mf}	Energy input of gaseous fuel per unit mass	kJ/kg
E_{Vf}	Energy input of the fuel per unit volume	kJ/m ³
E_{fin}	Fuel energy input	kJ
$E_{finstbat}$	Fuel energy input required during 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
H	Heating value	
H_{f0}	Heating value of fuel on a molar basis under reference conditions	kJ/mol
H_{f0j}	Heating value of component j at reference temperature T_0	kJ/mol

Symbol	Definition	Unit
H_{fl}	Heating value of liquid fuel	kJ/kg
M	Molar mass	
M_f	Molar mass of fuel	kg/mol
m	Mass	
m_f	Fuel mass measured over the test duration	kg
m_{HR}	Heat recovery fluid mass	kg
P, dP	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
dP_{down}	Decrease rate of electric power output	kW/s
dP_{up}	Increase rate of electric power output	kW/s
p	Pressure	
p_0	Reference pressure (101,325 kPa(abs))	kPa(abs)
p_f	Average fuel pressure	kPa(abs)
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_{VT0}	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	

Symbol	Definition	Unit
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	
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 ($2,364\ 5 \times 10^{-2}$ m ³ /mol at reference temperature $T_0 = 288,15$ K or $2,241\ 4 \times 10^{-2}$ 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	

Symbol	Definition	Unit
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 electric efficiency during one year of operation	%
$\eta_{el,est}(k)$	Estimated electric efficiency at the end of year k	%
$\eta_{el,init}$	Calculated value of the linear regression of the electric efficiency at the time of point a	%
$\Delta\eta_{el}$	Approximated degradation rate of the electric efficiency	%/h
$\eta_{th,est}(k)$	Estimated heat recovery efficiency at the end of year k	%
ρ	Density	
ρ_{HR}	Density of heat recovery fluid at T_{HR1}	kg/m ³

NOTE The main symbols in the fuel cell power system are found in Figure 1.



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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	
$M_r(\text{CO}_2)$	Relative molecular mass of CO_2 ($M_r(\text{CO}_2) \approx 44,01$)	
$M_r(\text{CO})$	Relative molecular mass of CO ($M_r(\text{CO}) \approx 28,01$)	
$M_r(\text{THC})$	Compositional relative molecular mass of THC	
$M_r(\text{NO}_x)$	Relative molecular mass of NO_x when the entire amount of NO_x is assumed to be NO_2 ($M_r(\text{NO}_x) \approx 46,01$)	
$M_r(\text{SO}_2)$	Relative molecular mass of SO_2 ($M_r(\text{SO}_2) \approx 64,06$)	
q_m	Mass discharge rate	
$q_{m,ex}(\text{CO}_2)$	CO_2 mass discharge rate by the exhaust	g/h

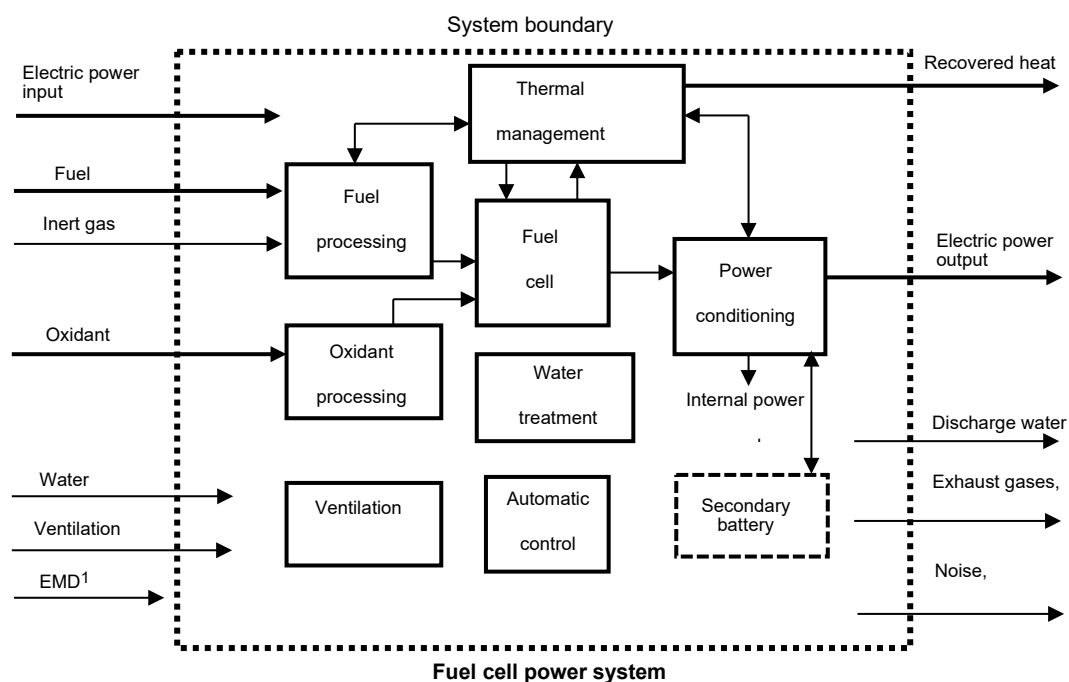
Symbol	Definition	Unit
$q_{m,ex}(\text{CO})$	CO mass discharge rate by the exhaust	g/h
$q_{m,ex}(\text{THC})$	THC mass discharge rate by the exhaust	g/h
$q_{m,ex}(\text{NO}_x)$	NO _x mass discharge rate by the exhaust	g/h
$q_{m,ex}(\text{SO}_2)$	SO ₂ mass discharge rate by the exhaust	g/h
V	Volume ratio	
$V_{ex,th,dr,V}$	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
$V_f(\text{H}_2)$	Volume ratio of H ₂ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{CO})$	Volume ratio of CO in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{CO}_2)$	Volume ratio of CO ₂ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{N}_2)$	Volume ratio of N ₂ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{CH}_4)$	Volume ratio of CH ₄ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{C}_2\text{H}_6)$	Volume ratio of C ₂ H ₆ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{C}_3\text{H}_8)$	Volume ratio of C ₃ H ₈ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{C}_4\text{H}_{10})$	Volume ratio of C ₄ H ₁₀ in unit volume per volume of input fuel	m ³ /m ³
$V_f(\text{C}_5\text{H}_{12})$	Volume ratio of C ₅ H ₁₂ in unit volume per volume of input fuel	m ³ /m ³
w	Mass fraction	
$w(\text{C})$	Mass fraction of the element C in unit mass of input fuel	kg/kg
$w(\text{H})$	Mass fraction of the element H in unit mass of input fuel	kg/kg
$w(\text{S})$	Mass fraction of the element S in unit mass of input fuel	kg/kg
$w(\text{N})$	Mass fraction of the element N in unit mass of input fuel	kg/kg
$w(\text{O})$	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	
$\alpha(\text{THC})$	Hydrogen to carbon atom ratio of THC in exhaust gas	
γ	Mass concentration	
$\gamma_{ex}(\text{CO})$	CO mass concentration in dry exhaust gas	mg/m ³
$\gamma_{ex}(\text{H}_2)$	H ₂ mass concentration in dry exhaust gas	mg/m ³
$\gamma_{ex}(\text{THC})$	THC mass concentration in dry exhaust gas	mg/m ³
$\gamma_{ex}(\text{NO}_x)$	NO _x mass concentration in dry exhaust gas	mg/m ³
$\gamma_{ex}(\text{SO}_2)$	SO ₂ mass concentration in dry exhaust gas	mg/m ³
ε	Emission	
$\varepsilon(\text{CO})$	Mass of CO emission per unit energy of fuel input	mg/kW·h
$\varepsilon(\text{THC})$	Mass of THC emission per unit energy of fuel input	mg/kW·h
$\varepsilon(\text{NO}_x)$	Mass of NO _x emission per unit energy of fuel input	mg/kW·h
$\varepsilon(\text{SO}_2)$	Mass of SO ₂ emission per unit energy of fuel input	mg/kW·h
ρ	Density	
$\rho(\text{CO})$	CO density	kg/m ³
$\rho(\text{H}_2)$	H ₂ density	kg/m ³
$\rho(\text{NO}_2)$	NO ₂ density	kg/m ³

Symbol	Definition	Unit
$\rho(\text{SO}_2)$	SO ₂ density	kg/m ³
φ	Volume fraction	
$\varphi_{\text{B,corr}}$	Corrected volume fraction of the component B	ml/m ³ , vol %
$\varphi_{\text{B,meas}}$	Measured volume fraction of the component B	ml/m ³ , vol %
$\varphi_{\text{at}}(\text{O}_2)$	Measured value of O ₂ volume fraction in atmosphere at air inlet in dry state (in case of fresh air, $\varphi_{\text{at}}(\text{O}_2) \approx 21\%$)	vol %
$\varphi_{\text{ex}}(\text{O}_2)$	Measured O ₂ volume fraction in dry exhaust gas	vol %
$\varphi_{\text{ex,corr}}(\text{CO}_2)$	Corrected CO ₂ volume fraction in dry exhaust gas	vol %
$\varphi_{\text{ex,corr}}(\text{CO})$	Corrected CO volume fraction in dry exhaust gas	ml/m ³
$\varphi_{\text{ex,corr}}(\text{H}_2)$	Corrected H ₂ volume fraction in dry exhaust gas	ml/m ³
$\varphi_{\text{ex,corr}}(\text{THC})$	Corrected THC volume fraction in dry exhaust gas (carbon equivalent)	ml/m ³
$\varphi_{\text{ex,corr}}(\text{NO}_x)$	Corrected NO _x volume fraction in dry exhaust gas	ml/m ³
$\varphi_{\text{ex,corr}}(\text{SO}_2)$	Corrected SO ₂ volume fraction in dry exhaust gas	ml/m ³

299

300 5 Configuration of small stationary fuel cell power system

301 Figure 2 illustrates the general configuration of small stationary fuel cell power systems subject
 302 to this document and shows the system boundary and physical quantities entering and leaving
 303 the fuel cell power system.



304

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305 Key

306 ¹ EMD electromagnetic disturbance

307 ² EMI electromagnetic interference

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

6 Reference conditions

The reference conditions are specified as follows:

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

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

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

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

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:

- 344 – electrical efficiency;
- 345 – heat recovery efficiency;
- 346 – overall energy efficiency.

347 NOTE See also Annex A in IEC 62282-3-200:2015.

348 8.3 Data acquisition plan

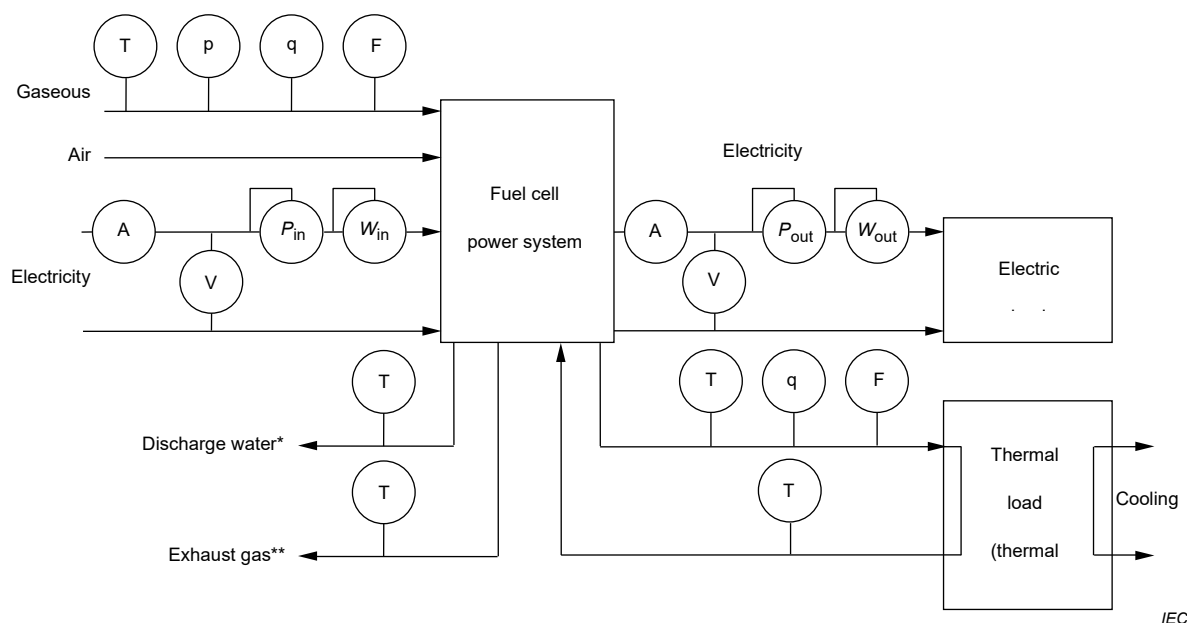
349 In order to meet the target uncertainty, proper duration and frequency of readings shall be
350 defined and suitable data recording equipment shall be prepared before the performance test.

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

352 9 Test set-up

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

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

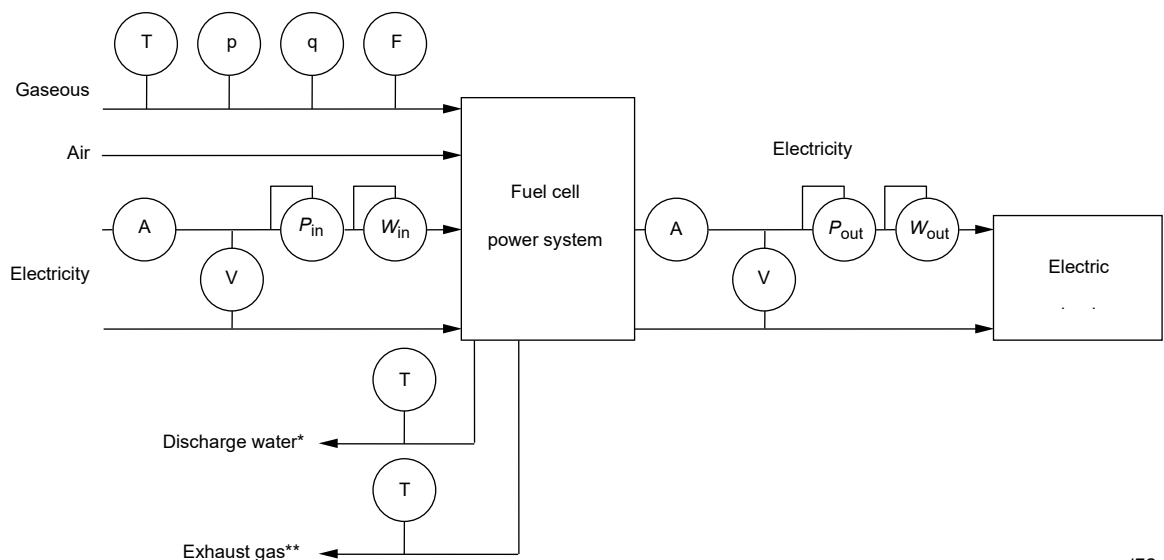


365

366 Key

367 See key for Figure 4.

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



IEC

Key

- $\textcircled{A}$ ammeter
- $\textcircled{V}$ voltmeter
- $\textcircled{T}$ thermometer
- $\textcircled{p}$ pressure gauge
- $\textcircled{q}$ flowmeter
- $\textcircled{F}$ integrating flowmeter
- $\textcircled{P}$ electric power meter
- $\textcircled{W}$ electric energy meter

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

** to collecting device to analyse components

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;
 - 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;
 - time-weighted characteristic: S;
 - 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. 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. 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, BOD probes.

NOTE BOD means biochemical oxygen demand, COD stands for chemical oxygen demand, and THC is total hydrocarbon.

10.3 Measurement points

Measurement points for different parameters are described below.

- a) Gaseous fuel flow rate:

- 435 place a flowmeter for fuel on the fuel supply line to the fuel cell power system to measure
436 the fuel flow rate.
- 437 b) Gaseous integrated fuel input:
438 place an integrating flowmeter for fuel on the fuel supply line to the fuel cell power system
439 to measure the fuel input. The integrating flowmeter may combine a flowmeter that
440 measures the fuel flow rate.
- 441 c) Liquid fuel input mass:
442 place scales under the fuel tank or the entire system, including the fuel tank, to measure
443 the mass of fuel.
- 444 d) Fuel temperature:
445 connect a thermometer immediately downstream of the fuel flowmeter.
- 446 e) Fuel pressure:
447 place a pressure meter immediately downstream of the fuel flowmeter to measure the gauge
448 pressure of fuel.
- 449 f) Electric power output:
450 connect an electric power meter to the electric power output terminal of the fuel cell power
451 system and close to the system boundary.
- 452 g) Electric power input:
453 connect an electric power meter to the electric power input terminal of the fuel cell power
454 system and close to the system boundary. In case no separate electric power input terminal
455 is existing, this measuring point can be substituted with the electric power output, providing
456 that it is equipped with a bidirectional meter.
- 457 h) Electric energy output:
458 connect an electric energy meter to the electric power output terminal of the fuel cell power
459 system and close to the system boundary. The electric energy meter may incorporate an
460 electric power meter that indicates electric power output.
- 461 i) Electric energy input:
462 connect an electric energy meter to the electric power input terminal of the fuel cell power
463 system and close to the system boundary. The electric energy meter may incorporate an
464 electric power meter that indicates electric power input. In case no separate electric energy
465 input terminal is existing, this measuring point can be substituted with the electric energy
466 output, providing that it is equipped with a bidirectional meter.
- 467 j) Fuel composition:
468 the fuel used during the tests shall be sampled either from the fuel tank or the supply line
469 and analysed on its composition. Fuel sampling and analysis are not required if pre-
470 analysed bottled fuel is used, provided that the uncertainty of the analysed gas is consistent
471 with the uncertainty required by the test.
- 472 k) Heat recovery fluid flow rate (only in utilization of heat):
473 place a fluid flowmeter on the heat recovery fluid circulation line (outgoing line or returning
474 line) that is plumbed between the fuel cell power system and the thermal load and close to
475 the system boundary. The circulation line shall be insulated to minimize heat loss.
- 476 l) Integrated heat recovery fluid flow (only in utilization of heat):
477 place an integrating flowmeter on the heat recovery fluid circulation line (outgoing line or
478 returning line) that is plumbed between the fuel cell power system and the thermal load and
479 close to the system boundary. An integrating flowmeter may incorporate a flowmeter that
480 indicates the flow rate of the heat recovery fluid.
- 481 m) Outgoing heat recovery fluid temperature (only in utilization of heat):
482 place a thermometer on the outgoing heat recovery fluid line and close to the system
483 boundary.
- 484 n) Returning heat recovery fluid temperature (only in utilization of heat):
485 place a thermometer on the returning heat recovery fluid line and close to the system
486 boundary.
- 487 o) Composition of heat recovery fluid (only in utilization of heat):