



BSI Standards Publication

Fuel cell technologies

Part 4-102: Fuel cell power systems for industrial electric trucks
— Performance test methods (IEC 62282-4-102:2017)

National foreword

This British Standard is the UK implementation of EN 62282-4-102:2017. It is identical to IEC 62282-4-102:2017.

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 secretary.

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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

**Fuel cell technologies - Part 4-102: Fuel cell power systems for
industrial electric trucks - Performance test methods
(IEC 62282-4-102:2017)**

Technologies des piles à combustible - Partie 4-102:
Systèmes à piles à combustible pour chariots de
manutention électriques - Méthodes d'essai des
performances
(IEC 62282-4-102:2017)

Brennstoffzellen-Technologien - Teil 4-102: Antriebe mit
Brennstoffzellen-Energiesystemen für elektrisch betriebene
Flurförderfahrzeuge - Leistungskennwerteprüfverfahren
(IEC 62282-4-102:2017)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European foreword

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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) 2018-02-15
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2020-05-15

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.

Endorsement notice

The text of the International Standard IEC 62282-4-102:2017 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 standards indicated:

IEC 62282-3-200	NOTE	Harmonized as EN 62282-3-200.
IEC 62282-4-101	NOTE	Harmonized as EN 62282-4-101
ISO 6060	NOTE	Harmonized as EN ISO 6060
ISO 6976	NOTE	Harmonized as EN ISO 6976
ISO 10523	NOTE	Harmonized as EN ISO 10523

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When 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 61672-1	-	Electroacoustics - Sound level meters -- Part 1: Specifications	EN 61672-1	-
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 62282-3-201	-
IEC 62282-6-300	-	Fuel cell technologies -- Part 6-300: Micro fuel cell power systems - Fuel cartridge interchangeability	EN 62282-6-300	-
ISO 9000	-	Hydrogen fuel_ - Product specification_ -	EN ISO 9000	-
ISO 14687-2	-	Part_2: Proton exchange membrane_(PEM) fuel cell applications for road vehicles	-	-

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CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	9
4 Symbols	11
5 Reference conditions	13
6 Heating value base.....	13
7 Test preparation	14
7.1 General.....	14
7.2 Data acquisition plan	14
8 Test setup	14
9 Instruments and measurement methods	16
9.1 General.....	16
9.2 Measurement instruments	16
9.3 Measurement points.....	17
9.4 Minimum required measurement systematic uncertainty.....	18
10 Test conditions	18
10.1 Laboratory conditions.....	18
10.2 Installation and operating conditions of the system	18
10.3 Indication of battery condition	18
10.4 Quality of test fuel.....	18
10.4.1 Hydrogen.....	18
10.4.2 Methanol solution	19
11 Fuel consumption test.....	19
11.1 Hydrogen fuel consumption test	19
11.1.1 General	19
11.1.2 Test method	19
11.1.3 Calculation of results	19
11.2 Methanol fuel consumption test.....	21
11.2.1 General	21
11.2.2 Test method	21
11.2.3 Calculation of average methanol fuel power input	21
12 Electrical power output test.....	22
12.1 General.....	22
12.2 Test method.....	22
12.3 Calculation of average electrical power output	22
12.4 Computation of electrical efficiency.....	23
13 Type tests on operational performance	23
13.1 Cold start maximum power output test	23
13.1.1 General	23
13.1.2 Test method	23
13.1.3 Processing of data	23
13.2 Power cycling electrical load test	23
13.2.1 General	23

13.2.2	Test method	23
13.2.3	Processing of data	24
13.3	Accessory load voltage spike test	24
13.3.1	General	24
13.3.2	Test method	24
13.3.3	Data processing.....	24
14	Power stability under the operation	24
14.1	General.....	24
14.2	Power delivered	24
14.3	Power absorbed.....	25
15	Type tests on environmental performance	25
15.1	General.....	25
15.2	Noise test	25
15.2.1	General	25
15.2.2	Test conditions	26
15.2.3	Test method	27
15.2.4	Processing of data	27
15.3	Exhaust gas test	27
15.3.1	General	27
15.3.2	Components to be measured	27
15.3.3	Test method	28
15.3.4	Processing of data	28
15.4	Discharge water test	30
15.4.1	General	30
15.4.2	Test method	30
16	Test reports	30
16.1	General.....	30
16.2	Title page.....	31
16.3	Table of contents	31
16.4	Summary report	31
Annex A (informative)	Heating values for hydrogen and methanol at reference conditions	32
Annex B (informative)	Guidelines for the contents of detailed and full reports	33
B.1	General.....	33
B.2	Detailed report	33
B.3	Full report	33
Bibliography		34
Figure 1	Fuel cell power systems for industrial electric trucks	10
Figure 2	Example of a test setup for hydrogen fuel	15
Figure 3	Example of a test setup for methanol fuel.....	16
Figure 4	Noise measurement points for fuel cell power systems.....	26
Table 1	Symbols and their meanings for electric/thermal performance	12
Table 2	Symbols and their meanings for environmental performance	13
Table 3	Power delivered measurements.....	25
Table 4	Power absorbed measurements	25

Table 5 – Compensation of readings against the effect of background noise.....	27
Table A.1 – Heating values for hydrogen and methanol at reference conditions	32

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FUEL CELL TECHNOLOGIES –

**Part 4-102: Fuel cell power systems for industrial electric trucks –
Performance test methods**

FOREWORD

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International Standard IEC 62282-4-102 has been prepared by IEC technical committee 105: Fuel cell technologies.

The text of this standard is based on the following documents:

FDIS	Report on voting
105/635/FDIS	105/642/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

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

INTRODUCTION

This part of IEC 62282-4 provides consistent and repeatable test methods for the electric/thermal and environmental performance of fuel cell power systems for industrial electric trucks.

The IEC 62282-4 series deals with categories such as safety, performance, and interchangeability of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APUs). Among the categories mentioned above, this document (IEC 62282-4-102) focuses on fuel cell power systems for industrial electric trucks because such an application is urgently demanded in the world.

This part of IEC 62282-4 describes type tests and their test methods only. No routine tests are required or identified, and no performance targets are set in this standard.

Fuel cells used in industrial electric trucks, such as forklift trucks, are hybrids and so operate in several different modes. Similarly, forklift trucks operate in different modes. The purpose of this document is to evaluate the fuel cell system in the various combinations of fuel cell modes and forklift truck modes. This document will break down these different modes and provide a framework for designing and evaluating a fuel cell system for use specifically in a forklift truck.

This part of IEC 62282-4 is to be used by manufacturers of fuel cell power systems used for industrial electric trucks and/or those who evaluate the performance of their systems for certification purposes.

Users of this document 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 4-102: Fuel cell power systems for industrial electric trucks – Performance test methods

1 Scope

This document covers performance test methods of fuel cell power systems intended to be used for electrically powered industrial trucks.

The scope of this document is limited to electrically powered industrial trucks. Hybrid trucks that include an internal combustion engine are not included in the scope. The scope of this standard will be applicable to material-handling equipment, e.g. forklifts.

This document applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.

The following fuels are considered within the scope of this standard:

- gaseous hydrogen, and
- methanol.

This document does not apply to reformer-equipped fuel cell power systems.

This document covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system. A fuel source container of the detachable type is not permitted.

This document applies to DC type fuel cell power systems, with a rated output voltage not exceeding 150 V DC for indoor and outdoor use.

Fuel cell power systems intended for operation in potentially explosive atmospheres are excluded from the scope of this document.

This document does not cover the fuel storage systems using liquid hydrogen.

All systems with integrated energy storage systems are covered by this document. This includes systems, for example, batteries for internal recharges or recharged from an external source.

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

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

IEC 62282-6-300, *Fuel cell technologies – Part 6-300: Micro fuel cell power systems – Fuel cartridge interchangeability*

ISO 9000, *Quality management series of standards*

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

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 standardisation 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 measured at a specified distance in all operation modes

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 support parasitic loads and/or provides electrical 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 at ambient temperature with no power input or output

[SOURCE: IEC/TS 62282-1:2013, 3.110.1]

3.5

discharge rate

mass of discharged exhaust gas component per unit of time

3.6

discharge water

water 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.

[SOURCE: IEC/TS 62282-1:2013, 2.2, modified – Note 1 to entry added.]

3.7

fuel cell system electrical efficiency

ratio of the average electric power output of a fuel cell power system at a given duration to the average fuel power fed to the same fuel cell power system at the same duration

3.8

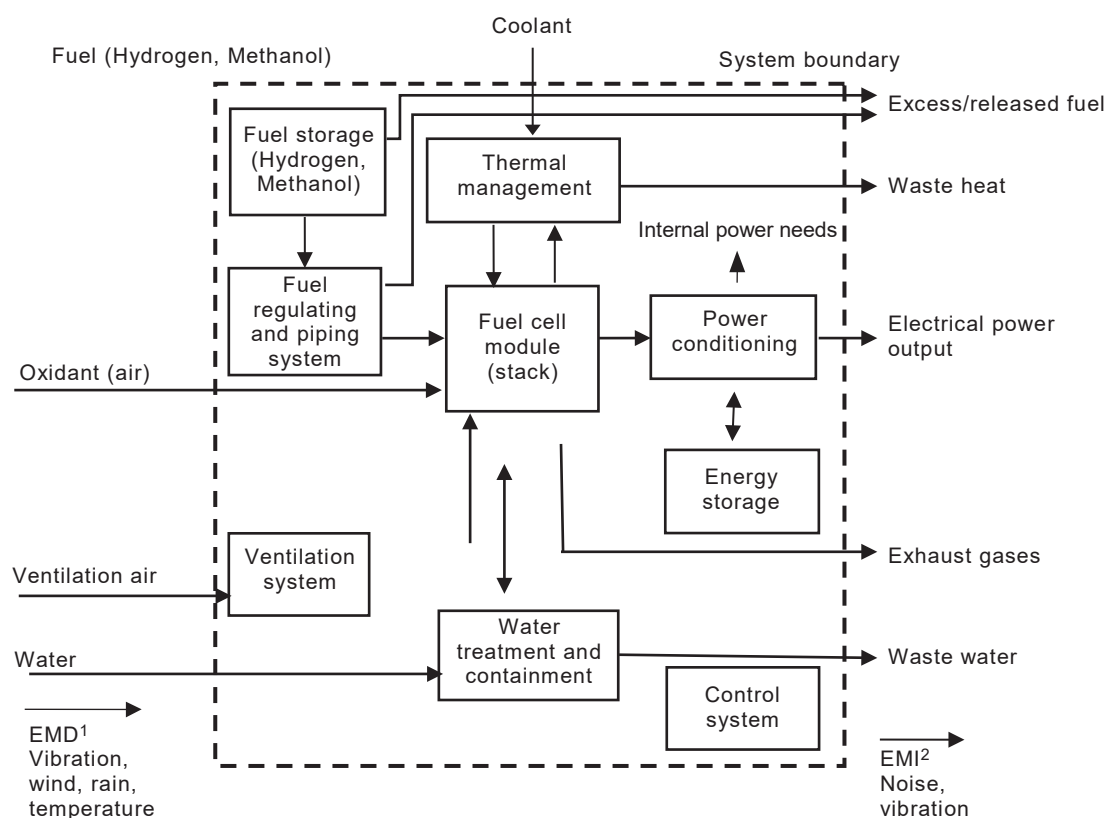
fuel cell power system

generator system that uses one or more fuel cell module(s) to generate electric power and heat

Note 1 to entry: See Figure 1 for a block diagram of a fuel cell power system.

Note 2 to entry: A fuel cell power system may contain all or some of the components shown in Figure 1. The fuel cell power system for use with industrial trucks will be in one of the forms as outlined in 3.9 and 3.10 of IEC 62282-4-101.

[SOURCE: IEC/TS 62282-1:2013, 3.49, modified – New Note 1 to entry has been added, and existing Note 1 to entry has become Note 2 to entry with the addition of the second sentence.]



IEC

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.

¹ EMD electromagnetic disturbance

² EMI electromagnetic interference

Figure 1 – Fuel cell power systems for industrial electric trucks

3.9

fuel input

amount of hydrogen or methanol supplied to the fuel cell power system

3.10**fuel power consumption**

amount of energy per time unit contained in the fuel consumed by the fuel cell power system

3.11**fuel consumption**

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

3.12**minimum electric power output**

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

3.13**rated power**

maximum continuous electric output power that a fuel cell power system (3.8) is designed to achieve under normal operating conditions specified by the manufacturer

[SOURCE: IEC/TS 62282-1:2013, 3.85.4, modified – Note 1 to entry deleted]

3.14**auxiliary load**

power consumed by auxiliary machines and equipment such as balance of plant (BOP) necessary to operate a fuel cell power system

3.15**storage state**

condition of a fuel cell power system that is non-operational and possibly requiring, under conditions specified by the manufacturer, the input of thermal or electric energy 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/TS 62282-1:2013, 3.110.6, modified – Reference to an inert atmosphere has been deleted, "and/or energize control systems and other components, and is ready for start-up" has been added.]

3.16**test duration**

time interval in which data points required for the computation of test results are recorded

4 Symbols

The symbols and their meanings used in this part of IEC 62282-4 are given in Table 1 for electric/thermal performance and in Table 2 for environmental performance, with the appropriate units.

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

Symbol	Definition	Unit
M, m	Molar mass, mass	
M_{mf}	Molar mass of fuel	g/mol
p	Pressure	
p_0	Reference pressure (101,325 kPa (abs))	kPa (abs)
p_f	Average fuel pressure	kPa (abs)
P, dP	Power, power change rate	
P_n	Average net electric power output	kW
P_{inf}	Average fuel power input	kJ/s
E	Input energy	
E_{fm}	Input energy of fuel (mass and volume)	kJ/kg
E_{inf}	Total fuel input energy	kJ
q_m	Mass flow rate	
q_{mf}	Average mass flow rate of fuel	kg/s
q_v	Volumetric flow rate	
q_{vf}	Average volumetric flow rate of fuel under the test conditions	l/min
q_{vf0}	Average volumetric flow rate of fuel under reference conditions	l/min
H	Heating value	
H_{f0}	Heating value of fuel on a molar basis under reference conditions	kJ/mol
t	Time	
Δ_t	Test duration	s
T	Temperature	
T_0	Reference temperature (273,15 K)	K
T_f	Average fuel temperature	K
ΔT	Temperature difference between heat recovery fluid output and input	K
V	Volume, molar volume	
V_{m0}	Reference molar volume of ideal gas (22,414 l/mol) (at reference temperature $T_0 = 273,15$ K and pressure $p_0 = 101,325$ kPa)	m ³ /mol
W	Electric energy	
W_{out}	Electric energy output	kW·h
η	Efficiency	
η_e	Electric efficiency	%
η_{th}	Heat recovery efficiency	%
η_{total}	Overall energy efficiency	%

Table 2 – Symbols and their meanings for environmental performance

Symbol	Definition	Unit
Φ	Volume fraction	
$\varphi_{B, meas}$	the measured volume fraction of each component	vol % or ml/m ³
$\varphi_{B, corr}$	the corrected volume fraction of each component	vol % or ml/m ³
$\varphi_{at(O_2)}$	the measured O ₂ (oxygen) volume fraction in atmosphere at air inlet in dry state	vol %
$\Phi_{ex(O_2)}$	measured O ₂ volume fraction in dry exhaust gas	vol %
$\varphi_{ex(CO)corr}$	the corrected CO volume fraction in dry exhaust gas	ml/m ³
$\varphi_{ex(THC)corr}$	the corrected THC volume fraction in dry exhaust gas	ml/m ³ C equivalent
Γ	Mass concentration	
$\gamma_{ex(CO)}$	the CO mass concentration in dry exhaust gas	mg/m ³
$\gamma_{ex(THC)}$	the THC mass concentration in dry exhaust gas	mg/m ³
ε	Emission	
ε_{CO}	the mass of CO emission per unit energy of input fuel	mg/kW·h
ε_{THC}	the mass of THC per unit energy of fuel input	mg/kW·h
α	Atom ratio	
α_{THC}	the hydrogen to carbon atom ratio of the THC in the exhaust gas.	
H	Heating value	

5 Reference conditions

The reference conditions are specified as follows:

- reference temperature: $T_0 = 273,15$ K (0 °C);
- reference pressure: $p_0 = 101,325$ kPa (abs).

6 Heating value base

Except if otherwise specified, the given heating value of fuel shall be the low heating value (LHV) or similar.

NOTE 1 The heating values of hydrogen and methanol (LHV and HHV) are given in Annex A.

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

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

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

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

7 Test preparation

7.1 General

This clause 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 part of IEC 62282-4 as their basis. A written test plan shall be prepared.

The following items shall be considered for the test plan:

- 1) objective;
- 2) test specifications;
- 3) test personnel qualifications;
- 4) quality assurance standards (ISO 9000 series of standards or other equivalent standards);
- 5) target uncertainty;
- 6) identification of measurement instruments (refer to Clause 9);
- 7) estimated range of test parameters;
- 8) data acquisition plan.

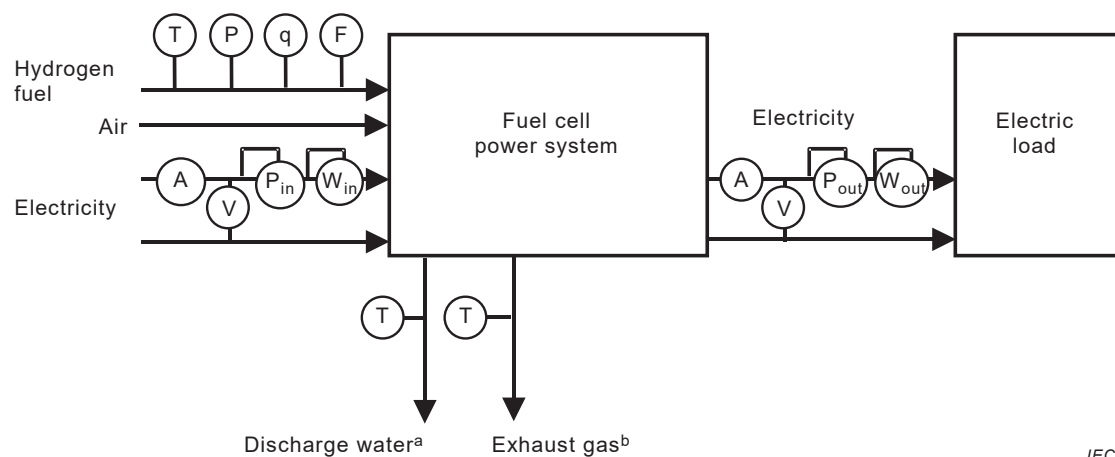
7.2 Data acquisition plan

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

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

8 Test setup

Figure 2 and Figure 3 illustrate examples of test setups that are required to conduct fuel cell power system testing with hydrogen fuel and methanol fuel, respectively, which are described in this document. An electric load is connected to a fuel cell power system.



IEC

^a To collecting device to measure volume (or weight), pH, BOD, COD

^b To collecting device to analyze components

(A) ammeter

(V) voltmeter

(T) thermometer

(P) pressure gauge

(q) flowmeter

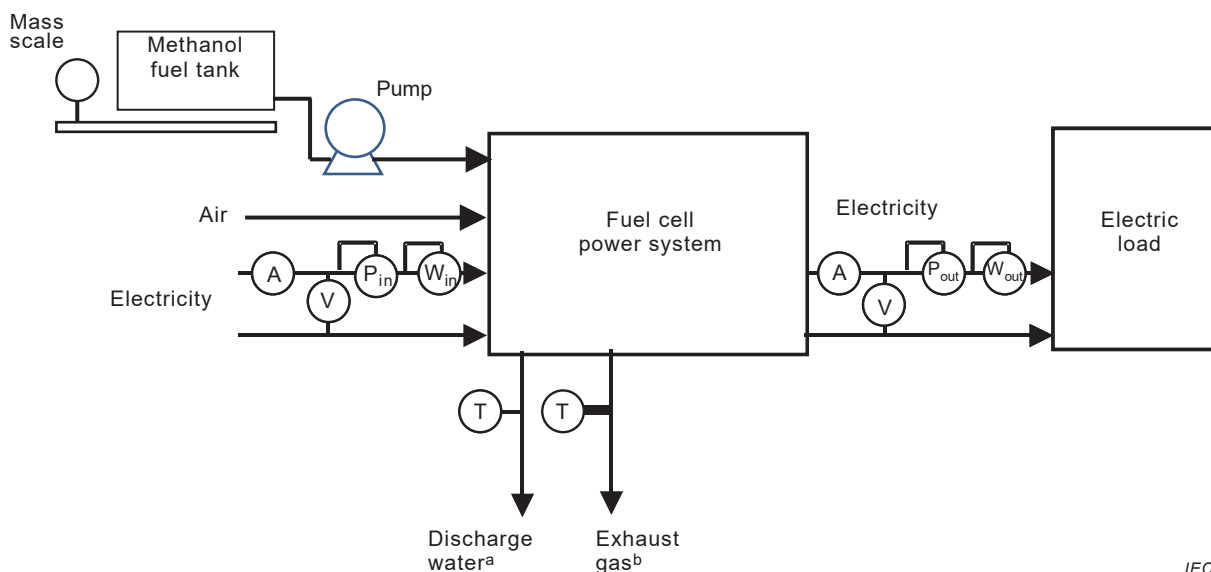
(F) integrating flowmeter

(P) electric power meter

(W) integrating electric power meter (electric energy meter)

Figure 2 – Example of a test setup for hydrogen fuel

NOTE See explanations of the symbols in Figure 2.



^a To collecting device to measure volume (or weight), pH, BOD, COD

^b To collecting device to analyse components

Figure 3 – Example of a test setup for methanol fuel

9 Instruments and measurement methods

9.1 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.

9.2 Measurement instruments

Measurement instruments are listed according to their intended use:

- apparatus for measuring voltage spikes: oscilloscope, high-frequency analysers;
- apparatus for measuring the electric power input and output, and electric energy input and output:
 - electric power meters, electric energy meters, voltmeters, ammeters.
- apparatus for measuring fuel input:
 - flowmeters, integrating flowmeters, weight meters, pressure sensors, temperature sensors.
- apparatus for measuring ambient conditions:
 - barometers, hygrometers, and temperature sensors.
- apparatus for measuring the noise level:
 - sound level meters as specified in IEC 61672-1 or other measuring instruments of equivalent or better accuracy.
- apparatus for measuring concentrations of the exhaust gas components:
 - oxygen analyzer (e.g. based on paramagnetic, electrochemical or zirconium oxide sensors);
 - carbon dioxide analyzer (e.g. GC-MS or based on infrared absorption sensor);

- carbon monoxide analyzer (e.g. based on nondispersive infrared or electrochemical sensor).
- g) apparatus for determining the discharge water:
- graduated cylinder (for volume measurement), temperature sensor, pH meters, BOD probes.

NOTE 1 BOD means Biochemical Oxygen Demand, COD stands for Chemical Oxygen Demand, and THC is Total Hydrocarbon.

9.3 Measurement points

Measurement points for the different parameters are described below.

- a) Hydrogen 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) Hydrogen 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 shall combine a flowmeter that measures the fuel flow rate.
- c) Methanol fuel input weight:
place a weight meter under the fuel tank to measure the weight of fuel and tank together. Methanol fuel input weight is measured by subtracting the weight after the test from that before the test.
- d) Fuel temperature:
connect a thermometer or a thermocouple 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 electrical power meter to the electrical power output terminal of the fuel cell power system and close to the system boundary.
- g) Electric energy output:
connect an electrical energy meter to the electrical power output terminal of the fuel cell power system and close to the system boundary. The electrical energy meter shall incorporate an electrical power meter that indicates electrical power output.
- h) Fuel composition:
the fuel used during the tests shall be sampled and analyzed on its composition.
- i) Atmospheric pressure:
place an absolute pressure meter adjacent to the fuel cell power system where it will not be affected by ventilation, air intake or exhaust of the fuel cell power system.
- j) Atmospheric temperature:
place a thermometer adjacent to the fuel cell power system where the thermometer will not be affected by ventilation, air intake or exhaust of the fuel cell power system.
- k) Atmospheric humidity:
place a hygrometer adjacent to the fuel cell power system where the hygrometer will not be affected by ventilation, air intake or exhaust of the fuel cell power system.
- l) Noise level:
refer to 15.2.
- m) Exhaust gas:

place one or more exhaust gas collecting probes combined with a temperature sensor in the exhaust stream at the exhaust gas outlet (refer to Figure 2 and Figure 3).

n) Discharge water:

place a discharge water reservoir combined with a temperature sensor at the discharge water outlet.

9.4 Minimum required measurement systematic uncertainty

The following systematic measurement uncertainties of the equipment are recommended. They are given in percentage of measured/calculated values or as absolute values:

- electric power: $\pm 1 \%$;
- electric energy: $\pm 1 \%$;
- fuel gas flow rate: $\pm 1 \%$;
- integrated gas flow: $\pm 1 \%$;
- time: $\pm 0,5 \%$;
- liquid fuel mass: $\pm 1 \%$ of the mass to be determined (not including the tare weight) as in IEC 62282-3-201;
- relative humidity: $\pm 5 \%$;
- absolute pressure: $\pm 1 \%$;
- fuel gas and discharge water temperature: $\pm 1 \text{ K}$;
- exhaust gas temperature: $\pm 4 \text{ K}$.

10 Test conditions

10.1 Laboratory conditions

Unless otherwise specified, performance shall be tested in the environment specified below:

- temperature: $20 \text{ }^{\circ}\text{C} \pm 5 \text{ }^{\circ}\text{C}$;
- humidity: $65 \pm 20 \%$ relative humidity;
- pressure: between 91 kPa (abs) and 106 kPa (abs).

For each test run, the laboratory conditions shall be measured during the test. As air quality shall affect fuel cell system performance, laboratory air composition (CO_2 , CO, SO_2 and so forth) shall be reported with the test result.

10.2 Installation and operating conditions of the system

The fuel cell power system shall be assembled and operated in accordance with the manufacturer's installation instructions prior to the start of the tests.

10.3 Indication of battery condition

For the systems with batteries, the battery SOC shall be constant at the beginning and at the end of the test duration.

10.4 Quality of test fuel

10.4.1 Hydrogen

Hydrogen fuel used for the tests shall have the quality given in Table 1 of ISO 14687-2.

10.4.2 Methanol solution

Methanol for preparing methanol solution which is used for the tests shall be consistent with the specification given in 5.5.2 of IEC 62282-6-300:2012.

Water mixed with methanol shall be ion-exchanged water with electrical conductivity of less than 1 $\mu\text{S}/\text{cm}$.

Methanol concentration in methanol solution shall be specified by the manufacturer.

11 Fuel consumption test

11.1 Hydrogen fuel consumption test

11.1.1 General

This test is for measuring the hydrogen fuel input at rated power output.

This test shall be carried out concurrently with the electrical power output test in Clause 12.

11.1.2 Test method

- 1) Operate the system at the rated power output for more than 30 min before starting the test.
NOTE Energy storage in the system reaches nominal state of charge after 30 min of operation.
- 2) For systems including electrochemical batteries, operate the system at rated power output for more than 30 min and until a known nominal state of charge is reached before starting the test.
- 3) Start the test while keeping the system operating at the nominal electric output power.
- 4) Measure the fuel temperature, fuel pressure, and integrated fuel input flow (in volume or in mass). Each measurement shall be taken for a minimum of 60 min.

11.1.3 Calculation of results

11.1.3.1 Calculation of average hydrogen fuel input rate

The average hydrogen fuel input rate shall be described either as the volumetric flow rate at reference conditions, q_{Vf0} in l/min, or as the mass flow rate, q_{mf} in kg/s. It shall be calculated according to the following procedure.

1) Volumetric flow rate

- a) The average volumetric flow rate of fuel under the test conditions, q_{Vf} in l/min, shall be obtained by dividing the integrated volumetric flow over the test duration by the test duration.

$$q_{Vf} = q_{iV} / \Delta_t \quad (1)$$

where

- q_{Vf} is the average volumetric flow rate of fuel under the test conditions (l/min);
 - q_{iV} is the total volumetric fuel flow over the test duration (l);
 - Δ_t is the test duration (min).
- b) The average volumetric flow rate of fuel under the reference conditions, q_{Vf0} in l/min, shall be calculated with the following formula. The average values of fuel temperature and pressure obtained during the test duration shall be used.

$$q_{Vf0} = q_{Vf} \times (T_0 / T_f) \times (p_f / p_0) \quad (2)$$