

TECHNICAL SPECIFICATION

SPECIFICATION TECHNIQUE

**Fuel cell technologies –
Part 7-2: Test methods – Single cell and stack performance tests for solid oxide
fuel cells (SOFC)**

**Technologies des piles à combustible –
Partie 7-2: Méthodes d'essai – Essais de performance de cellule élémentaire et
de pile pour les piles à combustible à oxyde solide (SOFC)**



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CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms, definitions and symbols.....	9
3.1 Terms and definitions.....	9
3.2 Symbols.....	11
4 General safety conditions	12
5 Cell/stack assembly unit	12
6 Testing system	13
6.1 Subsystems in testing system	13
6.1.1 General	13
6.1.2 Anode gas control subsystem	13
6.1.3 Cathode gas control subsystem	13
6.1.4 Cell/stack assembly unit temperature control subsystem.....	13
6.1.5 Output power control subsystem.....	14
6.1.6 Measurement and data acquisition subsystem.....	14
6.1.7 Safety subsystem	14
6.1.8 Mechanical load control subsystem.....	14
6.1.9 Gas pressure control subsystem for anode and cathode.....	14
6.1.10 Test system control subsystem.....	14
6.2 Maximum variation in control items of testing system	14
7 Instruments and measurement methods	15
7.1 General.....	15
7.2 Instrument uncertainty	15
7.3 Anode gas	15
7.3.1 Anode gas flow rate.....	15
7.3.2 Anode gas composition.....	16
7.3.3 Anode gas temperature	16
7.3.4 Anode gas pressure.....	17
7.3.5 Anode exhaust gas flow rate.....	17
7.3.6 Anode exhaust gas component.....	17
7.3.7 Anode exhaust gas temperature	17
7.3.8 Anode exhaust gas pressure.....	17
7.4 Cathode gas	18
7.4.1 Cathode gas flow rate.....	18
7.4.2 Cathode gas component.....	18
7.4.3 Cathode gas temperature	18
7.4.4 Cathode gas pressure.....	18
7.4.5 Cathode exhaust gas flow rate.....	18
7.4.6 Cathode exhaust gas component.....	19
7.4.7 Cathode exhaust gas temperature	19
7.4.8 Cathode exhaust gas pressure	19
7.5 Output voltage	19
7.6 Output current.....	19

7.7	Cell/stack assembly unit temperature	19
7.8	Mechanical load	19
7.9	Total impedance	20
7.10	Ambient condition	20
8	Test preparation	20
8.1	General.....	20
8.2	Standard test condition and test range	20
8.3	Components and impurities of anode gas and cathode gas	21
8.4	Basis of the test procedure	21
8.5	Confirmation of aging condition for unit.....	21
8.6	Confirmation of criteria of stable state.....	21
8.7	Data acquisition method.....	21
9	Test procedure	21
9.1	Set-up.....	21
9.2	Initial conditioning.....	22
9.3	Shut-down	22
10	Performance test	22
10.1	Rated power test.....	22
10.1.1	Objective	22
10.1.2	Test method	22
10.1.3	Presentation of results.....	22
10.2	Current-voltage characteristics test.....	23
10.2.1	Objective	23
10.2.2	Test method	23
10.2.3	Presentation of results.....	23
10.3	Effective fuel utilization dependency test	24
10.3.1	Objective	24
10.3.2	Test method	24
10.3.3	Presentation of results.....	24
10.4	Long term durability test	25
10.4.1	Objective	25
10.4.2	Test method	25
10.4.3	Presentation of results.....	26
10.5	Thermal cycling durability test.....	26
10.5.1	Objective	26
10.5.2	Test method	26
10.5.3	Presentation of results.....	27
10.6	Internal reforming performance test	27
10.6.1	Objective	27
10.6.2	Test method	27
10.6.3	Presentation of results.....	27
10.7	Resistance components identification test.....	27
10.7.1	Objective	27
10.7.2	Test method	28
10.7.3	Presentation of results.....	28
11	Test report.....	29
11.1	General.....	29
11.2	Report items	29

11.3	Test unit data description	30
11.4	Test condition description	30
11.5	Test data description	30
11.6	Uncertainty evaluation	30
Annex A (informative)	Example of cell assembly unit	31
Annex B (informative)	Calculation of effective fuel utilization	32
B.1	Calculation method	32
B.2	Calculation examples	33
B.2.1	Calculation from anode gas composition and flow-rate.....	33
B.2.2	Calculation from supplied H ₂ and H ₂ O flow rate	33
Annex C (informative)	Calculation of effective oxygen utilization	34
C.1	Calculation method	34
C.2	Calculation example.....	34
Annex D (informative)	Maximum width of the voltage hysteresis in <i>I-V</i> characteristic test	36
Annex E (informative)	Current-voltage characteristic test under constant effective fuel utilization	37
Annex F (informative)	Test report (template).....	38
F.1	General information	38
F.2	Test unit data description	38
F.3	Test condition	39
F.4	Rated power test.....	39
F.5	Current-voltage characteristics test.....	39
F.6	Effective fuel utilization dependency test	40
F.7	Long-term durability test	41
F.8	Thermal cycling durability test.....	42
F.9	Internal reforming performance test.....	42
F.10	Resistance components identification test.....	43
Annex G (informative)	Method for finding instrument uncertainty.....	44
Bibliography	45
Figure 1	– Testing system.....	13
Figure 2	– Typical diagram of complex impedance plot for SOFC.....	29
Figure A.1	– Example of cell assembly unit.....	31
Figure D.1	– Voltage hysteresis at a given sweep rate in <i>I-V</i> characteristic test	36
Figure E.1	– Example of the record in current-voltage characteristic test under constant effective fuel utilization	37
Table 1	– Symbols	11
Table B.1	– n_j for representative fuels	33
Table B.2	– Anode gas composition, flow rate of each fuel component f_j , and $n_j f_j$	33
Table C.1	– Cathode gas composition, f_{O_2} , and I_{theory}	35

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FUEL CELL TECHNOLOGIES –**Part 7-2: Test methods –
Single cell and stack performance tests for solid oxide fuel cells (SOFC)**

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62282-7-2, which is a technical specification, has been prepared by IEC technical committee 105: Fuel cell technologies.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
105/443/DTS	105/498/RVC

Full information on the voting for the approval of this technical specification 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 web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
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WITHDRAWN

INTRODUCTION

This technical specification describes test methods for a single cell and stack (denoted as "cell/stack" hereafter) that is to be employed in power generation systems using solid oxide fuel cells (SOFCs).

SOFCs have a broad range of geometry and size. As such, in general, peripherals like current collectors and gas manifolds are unique to each cell or stack and are often incorporated into a cell or stack to form one integrated unit. In addition, they tend to have a significant effect on the power generation characteristics of the cell or stack. This technical specification therefore introduces as its subject "cell/stack assembly units," which are defined as those units containing not only a cell or stack but also peripherals.

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FUEL CELL TECHNOLOGIES –

Part 7-2: Test methods – Single cell and stack performance tests for solid oxide fuel cells (SOFC)

1 Scope

This part of IEC 62282, which is a technical specification, provides for SOFC cell/stack assembly units, testing systems, instruments and measuring methods, and test methods to test the performance of SOFC cells and stacks.

This technical specification is not applicable to small button cells that are designed for SOFC material testing and provide no practical means of fuel utilization measurement.

This technical specification is to be used for data exchanges in commercial transactions between cell/stack manufacturers and system developers or for acquiring data on a cell or stack in order to estimate the performance of a system based on it. Users of this technical specification may selectively execute test items suitable for their purposes from those described in this technical specification.

2 Normative references

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.

IEC 60584-1, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60584-2, *Thermocouples – Part 2: Tolerances*

IEC 60584-3, *Thermocouples – Part 3: Extension and compensating cables – Tolerances and identification system*

IEC 61515, *Mineral insulated thermocouple cables and thermocouples*

IEC TS 62282-1:2013, *Fuel cell technologies – Part 1: Terminology*

ISO 4260, *Petroleum products and hydrocarbons – Determination of sulfur content – Wickbold combustion method*

ISO 5168, *Measurement of fluid flow – Procedures for the evaluation of uncertainties*

ISO 6141, *Gas analysis – Requirements for certificates for calibration gases and gas mixtures*

ISO 6142, *Gas analysis – Preparation of calibration gas mixtures – Gravimetric method*

ISO 6143, *Gas analysis – Comparison methods for determining and checking the composition of calibration gas mixtures*

ISO 6145-7, *Gas analysis – Preparation of calibration gas mixtures using dynamic volumetric methods – Part 7: Thermal mass-flow controllers*

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

ISO 7066-2, *Assessment of uncertainty in the calibration and use of flow measurement devices – Part 2: Non-linear calibration relationships*

ISO 8573-1, *Compressed air – Part 1: Contaminants and purity classes*

ISO 8756, *Air quality – Handling of temperature, pressure and humidity data*

ISO 12185, *Crude petroleum and petroleum products – Determination of density – Oscillating U-tube method*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62282-1, as well as the following terms and definitions, apply.

3.1.1

cell/stack assembly unit

unit including a single cell or stack, as well as gas supply parts, current collector parts, and any other peripherals as required for power generation tests

3.1.2

active electrode area

geometric electrode area upon which an electrochemical reaction occurs

Note 1 to entry: Usually this is the smaller of the anode and cathode areas.

3.1.3

current density

current divided by active electrode area

3.1.4

average cell voltage

cell/stack assembly unit voltage divided by the number of the cells in a series connection in the unit

3.1.5

normal temperature and pressure

NTP

0 °C and 101,325 kPa, respectively

3.1.6

anode gas

gas which is supplied to the inlet of the anode of a single cell/stack assembly unit

Note 1 to entry: Such a gas belongs to one of the following categories:

- pure hydrogen or mixture which contains hydrogen as a principal component with water vapour or nitrogen;
- reformed gas of raw fuel of SOFC such as methane or kerosene premixed with water vapour or air as oxidant;
- simulated gas of reformat which contains hydrogen, water vapour, carbon monoxide, carbon dioxide, methane, nitrogen, etc, as main components;
- methane, alcohols and other raw fuels directly supplied in pure form or mixed with water vapour and/or air.

3.1.7**cathode gas**

gas which is supplied to the inlet of the cathode of a single cell/stack assembly unit

Note 1 to entry: Oxygen and nitrogen are its main components.

3.1.8**current collector**

conductive material in a fuel cell that collects electrons from the anode side or conducts electrons to the cathode side

3.1.9**stable state**

condition of a cell/stack assembly unit at which the unit is stable enough for any controlling parameter and the output voltage or output current of the unit to remain within its tolerance range of variation

3.1.10**theoretical current**

current when the supplied anode gas or cathode gas is completely consumed in electrochemical reactions divided by the number of cells in a series connection

3.1.11**effective fuel utilization**

ratio of actual output current of the cell/stack assembly unit to the theoretical current

Note 1 to entry: Causes for less-than-optimal currents include losses due to electronic conduction within the cell/stack assembly, gas leaks and anode gas pass-through.

Note 2 to entry: Calculation method of effective fuel utilization is given in Annex B.

3.1.12**effective oxygen utilization**

ratio of actual output current of the cell/stack assembly unit to the theoretical current

Note 1 to entry: Calculation method of effective oxygen utilization is given in Annex C.

3.1.13**maximum effective fuel utilization**

highest effective fuel utilization that the unit can operate at, without causing unacceptable degradation

Note 1 to entry: The acceptable degradation rate is usually obtained from the developer.

3.1.14**minimum cell/stack assembly unit voltage**

lowest cell/stack assembly unit voltage specified by the manufacturer

3.1.15**open circuit voltage**

OCV

voltage across the terminals of a fuel cell with cathode and anode gases present and in the absence of external current flow

Note 1 to entry: Also known as no-load voltage.

3.1.16**power density**

ratio of the power to the active electrode area of a cell/stack assembly unit

Note 1 to entry: Power density is calculated from the voltage multiplied by the current density ($P_d = V \times J$, where J is current density).

3.1.17

total impedance

frequency-dependent losses due to ohmic, activation, diffusion, and concentration effects

3.1.18

total resistance

real part of low-frequency limit of total impedance which is the same as the slope of tangent to I - V curve

3.1.19

stoichiometric ratio

ratio between the number of moles of reactant gas flowing per unit time to that needed by the electrochemical reaction

Note 1 to entry: The terms, “stoichiometric ratio” and “reactant gas utilization,” are related. The reciprocal of the fraction of the gas utilized is the stoichiometric ratio.

3.2 Symbols

Table 1 shows the symbols and units that are used in this technical specification.

Table 1 – Symbols

Symbol	Definition	Unit
a	Error limit specified from specification of instrument	**
f_a	Flow rate of anode gas	l/min (NTP)
f_c	Flow rate of cathode gas	l/min (NTP)
f_j	Flow rate of fuel component j in anode gas	l/min (NTP)
I	Current	A
J	Current density	A/cm ²
n	Number of transferred electrons	
N	Number of cells in a series connection	
p_a	Absolute pressure of anode gas	kPa
p_c	Absolute pressure of cathode gas	kPa
P	Output power	W
P_d	Output power density	W/cm ²
t	Time	s, min, h
T_{op}	Cell/stack assembly unit operating temperature	°C
u_l	Combined standard uncertainty for instruments	**
$u_{l,i}$	Standard uncertainty for instrument i	**
U_f	Effective fuel utilization	%
U_{O_2}	Effective oxygen utilization	%
U_l	Extended instrument uncertainty	**
V	Voltage	V
x_i	Normalized mole fraction of component i	mol %
x_i^*	Non-normalized mole fraction of component i	mol %
ζ_j	Hydrocarbon conversion rate for hydrocarbon component j	%

** Denotes where the unit varies depending on the specification.

4 General safety conditions

An operating fuel cell uses oxidizing and combustible gases. Typically, these gases are stored in high-pressure containers. The fuel cell itself may be operated at pressures greater than atmospheric pressure. Those who carry out cell/stack assembly unit testing shall be trained and experienced in the operation of test systems and specifically in safety procedures involving electrical equipment and reactive, compressed gases.

The test personnel are responsible for obtaining and following all applicable safety codes and generally accepted engineering practices related to their test system, facility, fuels (with particular attention to compressed gases), and exhaust products.

Materials which are compatible with the use and storage of the reactant gases shall be used during testing. Local safety codes and standards for working with hydrogen, hydrocarbons and carbon monoxide should be followed.

In summary, safely operating a test station requires appropriate technical training and experience as well as safety facilities and equipment, all of which are outside the scope of this technical specification.

5 Cell/stack assembly unit

A cell/stack assembly unit includes a cell or stack, gas supply, current leads, and such other peripherals as required for power generation tests. It shall be provided with single or multiple measuring points for temperature and voltage, and one set of current lead points, all to be specified by the manufacturer.

As shown in Annex A, the boundary of a cell/stack assembly unit goes through the anode gas supply port, cathode gas supply port, temperature measuring point, current lead points, voltage measuring points and mechanical load application points.

Some cell/stack assembly units may have no exhaust port for the anode gas or cathode gas because of the configuration of the cells. In such cases, the gas flow field pattern and its material shall be determined by the method recommended by the manufacturer. The load application method shall be also based on the recommendation of the manufacturer. The maximum operating temperature from the manufacturer shall not be exceeded.

If the components of a cell/stack assembly unit other than a cell/stack are not specified by the manufacturer, the following shall be described in the test report, as a minimum:

- a) materials and geometry of the peripheral components to be used for testing;
- b) flow patterns and directions of anode and cathode gases;
- c) locations of temperature measurement, mechanical load application, voltage measurement and current leads;
- d) magnitude of the mechanical load;
- e) configuration of assembly unit and its assembling method.