



BSI Standards Publication

## Fuel cell technologies

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

### **National foreword**

This Published Document is the UK implementation of IEC/TS 62282-7-2:2014.

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2014.  
Published by BSI Standards Limited 2014

ISBN 978 0 580 79769 9  
ICS 27.070

### **Compliance with a British Standard cannot confer immunity from legal obligations.**

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 May 2014.

### **Amendments/corrigenda issued since publication**

Date	Text affected
------	---------------

---



# 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)**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX



---

ICS 27.070

ISBN 978-2-8322-1539-5

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## 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 <sub>2</sub> and H <sub>2</sub> 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

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

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

## 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.

## 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*