

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)**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2014 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

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 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

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.

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.

Withdrawn