

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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

**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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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## FUEL CELL TECHNOLOGIES –

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

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This second edition cancels and replaces the first edition published in 2021. This edition constitutes a technical revision.

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

- a) Table 1 has been revised to specify the units missing for some terms;
- b) bibliographical entries (ISO/TR 15916, SOCTESQA test modules and ISO/IEC Guide 98-6:2021) have been added to provide further information.

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

Draft	Report on voting
105/1093/FDIS	105/1099/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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

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## INTRODUCTION

Solid oxide fuel cells (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 document 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 (SOFCs)

#### 1 Scope

This part of IEC 62282 applies to SOFC cell/stack assembly units, testing systems, instruments and measuring methods, and specifies test methods to test the performance of SOFC cells and stacks.

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

This document is used based on the recommendation of the entity that provides the cell performance specification or for acquiring data on a cell or stack in order to estimate the performance of a system based on it. Users of this document can selectively execute test items suitable for their purposes from those described in this document.

Users can substitute selected test methods of this document with equivalent test methods of IEC 62282-8-101 for solid oxide cell (SOC) operation for energy storage purposes, operated in reverse or reversible mode.

#### 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 60050-485, *International Electrotechnical Vocabulary (IEV) – Part 485: Fuel cell technologies*, available at <https://www.electropedia.org>

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

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

IEC 61515, *Mineral insulated metal-sheathed thermocouple cables and thermocouples*

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

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, petroleum products and related products – Determination of density – Laboratory density meter with an oscillating U-tube sensor*

### 3 Terms, definitions and symbols

#### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-485 and the following apply.

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

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

##### 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 used in power generation tests

##### 3.1.2

#### **active electrode area**

geometric electrode area upon which an electrochemical reaction occurs

Note 1 to entry: Usually the active electrode area is the smaller of the anode and cathode areas.

##### 3.1.3

#### **current density**

current divided by the active electrode area

##### 3.1.4

#### **average repeating unit voltage**

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

##### 3.1.5

#### **anode gas**

gas that 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:

- a) pure hydrogen or mixture that contains hydrogen as a principal component with water vapour or nitrogen;
- b) reformed gas of raw fuel of SOFC such as methane or kerosene premixed with water vapour or air as oxidant;
- c) simulated gas of reformat that contains hydrogen, water vapour, carbon monoxide, carbon dioxide, methane, nitrogen, etc., as main components;
- d) methane, alcohols and other raw fuels directly supplied in pure form or mixed with water vapour or air, or both.
- e) condensable gas operating in gas phase such as anhydrous ammonia (NH<sub>3</sub>) as raw input fuel or in cracked form.

##### 3.1.6

#### **cathode gas**

gas that 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.

##### 3.1.7

#### **current collector**

conductive material in a cell/stack assembly unit that collects electrons from the anode side or conducts electrons to the cathode side

**3.1.8****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

**3.1.9****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

**3.1.10****effective fuel utilization**

ratio of the actual output current of the cell/stack assembly unit to the theoretical current that is calculated for the supplied fuel

Note 1 to entry: The effective utilization is the utilization of reactants in the electrochemical reaction at the anode due to the actual current. This can be less than the actual or total utilization if there are gas inlet and cross leaks.

Note 2 to entry: Causes of less-than-optimal currents include losses due to electronic conduction within the cell/stack assembly, gas leaks.

Note 3 to entry: A calculation method of effective fuel utilization is given in Annex B.

**3.1.11****effective oxygen utilization**

ratio of the actual output current of the cell/stack assembly unit to the theoretical current that is calculated for the supplied oxygen

Note 1 to entry: The effective utilization is the utilization of reactants in the electrochemical reaction at the cathode due to the actual current. This can be less than the actual or total utilization if there are gas inlet and cross leaks.

Note 2 to entry: A calculation method of effective oxygen utilization is given in Annex C.

**3.1.12****maximum effective fuel utilization**

highest effective fuel utilization that the cell/stack assembly unit can operate at, without causing unacceptable degradation

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

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

lowest cell/stack assembly unit voltage specified by the manufacturer

**3.1.14****open circuit voltage****OCV**

voltage across the terminals of a cell/stack assembly unit with cathode and anode gases present and in the absence of external current flow

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

**3.1.15****total impedance**

frequency-dependent losses due to ohmic, activation, diffusion, concentration effects, stray (parasitic) capacitance and inductances

**3.1.16****total resistance**

real part of the low-frequency limit of total impedance

**3.1.17****stoichiometric ratio**

ratio between the number of moles of reactant gas flowing per unit time to that used 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 lists the symbols and units that are used in this document.

**Table 1 – Symbols**

Symbol	Term	Unit
$a$	Error limit specified from specification of instrument	a
$I$	Current	A
$J$	Current density	A/cm <sup>2</sup>
$A$	Active electrode area	cm <sup>2</sup>
$Z$	Total impedance	Ω cm <sup>2</sup>
$n$	Number of transferred electrons	
$N$	Number of cells in a series connection in the cell/stack assembly unit	
$p_a$	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 <sup>2</sup>
$q_a$	Flow rate of anode gas	l/min (STP <sup>b</sup> )
$q_c$	Flow rate of cathode gas	l/min (STP)
$q_j$	Flow rate of fuel component $j$ in anode gas	l/min (STP)
$t$	Time	s, min, h
$T_{op}$	Cell/stack assembly unit operating temperature	°C or K
$u_c$	Combined standard uncertainty for instruments	a
$u_{1,i}$	Standard uncertainty for instrument $i$	a
$U_f$	Effective fuel utilization	%
$U_{O_2}$	Effective oxygen utilization	%
$U_1$	Instrument expanded uncertainty	a
$V$	Voltage	V
$x_i$	Molar fraction of component $i$ or mole percent of component $i$	mol/mol or mol % <sup>c</sup>
$c_i$	Concentration of component $i$	mol/m <sup>3</sup>
$\xi_j$	Hydrocarbon conversion rate for hydrocarbon component $j$	%
<p><sup>a</sup> Denotes where the unit varies depending on the specification.</p> <p><sup>b</sup> Abbreviation for standard temperature and pressure</p> <p><sup>c</sup> Mole percent expressed as one hundred times mole fraction.</p>		

## 4 General safety conditions

An operating fuel cell uses oxidizing and combustible gases. Typically, these gases are stored in high-pressure containers. In some cases, the fuel can be a toxic condensable gas (such as ammonia). The fuel cell itself can be operated at pressures greater than atmospheric pressure. Leaks or outlet flows from cell/stack assembly unit can contain toxic elements (e.g. when using ammonia as a fuel). 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, and toxic compounds if applicable (e.g. when using ammonia as a fuel).

Materials which are compatible with the use and storage of the reactant gases shall be used during testing.

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 document.

## 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. 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 assembly unit goes through the anode gas supply port, cathode gas supply port, temperature, pressure measuring point, current lead points, voltage measuring points and mechanical load application points.

Some cell/stack assembly units can 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 recommended by 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.

## 6 Testing system

### 6.1 Subsystems in testing system

#### 6.1.1 General

As shown in Figure 1, a testing system consists of an anode gas control subsystem, cathode gas control subsystem, cell/stack assembly unit temperature control subsystem, output power control subsystem, measurement and data acquisition subsystem and safety subsystem. It can also include a mechanical load control subsystem, anode gas and cathode gas pressure control subsystem or a test system control subsystem that controls the whole testing system, or both, if necessary.