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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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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,
- 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- withdrawn,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*

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:

a) pure hydrogen or mixture which 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 reformate which 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 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 withidn 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_I	Combined standard uncertainty for instruments	**
$u_{I,i}$	Standard uncertainty for instrument i	**
U_f	Effective fuel utilization	%
U_{o2}	Effective oxygen utilization	%
U_I	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 %
ξ_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.

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 may also include a mechanical load control subsystem, anode gas and cathode gas pressure control subsystem and/or a test system control subsystem that controls the whole testing system, if needed.

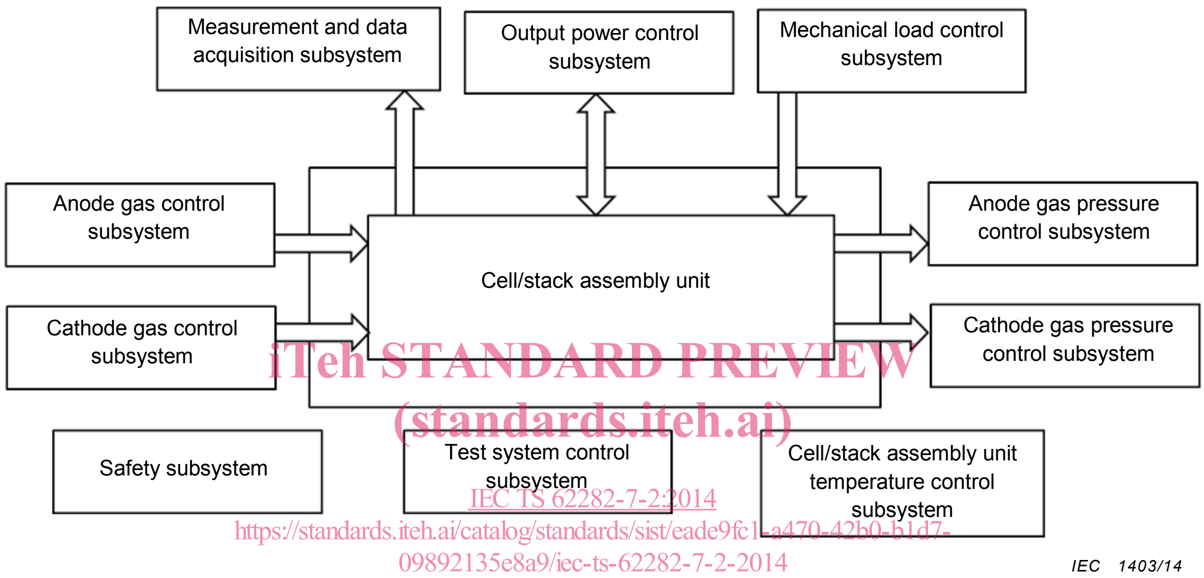

Figure 1 – Testing system

6.1.2 Anode gas control subsystem

The anode gas control subsystem controls the flow rate, composition and temperature of anode gas supplied to the cell/stack assembly unit. If the gas composition is to be maintained throughout the piping, then attention shall be paid to the materials, temperature, inner diameter and length of the piping. Where necessary, the piping shall be heated and/or thermally insulated in order to prevent condensation of water vapour.

Care should be taken to avoid other phenomena, such as carbon deposits, and the evaporation and transport of undesired materials in the gas streams, such as chromium.

6.1.3 Cathode gas control subsystem

The cathode gas control subsystem controls the flow rate, composition and temperature of the cathode gas supplied to the cell/stack assembly unit.

Care should be taken to avoid other phenomena, such as the evaporation and transport of undesired materials in the gas streams, such as chromium.

6.1.4 Cell/stack assembly unit temperature control subsystem

The cell/stack assembly unit temperature control subsystem controls, at least, the electric furnace or the unit temperature. It maintains the operating temperature. The electric furnace shall be selected to maintain the temperature distribution within the prescribed tolerance level.