IEC 62282-8-301

Edition 1.0 2023-05

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Fuel cell technologies – Part 8-301: Energy storage systems using fuel cell modules in reverse mode – Power-to-methane energy systems based on solid oxide cells including reversible operation – Performance test methods

Technologies des piles à combustible – Partie 8-301: Systèmes de stockage de l'énergie utilisant des modules à piles à combustible en mode inversé – Systèmes de conversion de l'énergie en méthane à base de piles à oxyde solide, comprenant le fonctionnement réversible – Méthodes d'essai des performances

IEC 62282-8-301:2023-05(en-fr)

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CONTENTS

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IEC 62282-8-301:2023
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FUEL CELL TECHNOLOGIES –

Part 8-301: Energy storage systems using fuel cell modules in reverse mode – Power-to-methane energy systems based on solid oxide cells including reversible operation – Performance test methods

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

Draft	Report on voting
105/968/FDIS	105/983/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.

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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. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62282 series, published under the general title *Fuel cell technologies*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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INTRODUCTION

This part of IEC 62282 describes performance evaluation methods for electric energy conversion systems based on power-to-methane systems using solid oxide cells (SOCs) and methanation reactors.

A typical application of the power-to-methane systems is an electrolytic production of methane as the energy carrier suitable for a large-scale, long-term storage and transportation.

The combustion heat of methane per mol is about three times larger than that of hydrogen. Methane is easily liquefied, which makes it suitable for storage and transportation via existing infrastructures for natural gas (tanks, pipelines, tankers, or trucks) as well as for being easily utilized by conventional equipment. Also, the use of "green methane" (produced by renewable electricity) or "carbon neutral methane" in place of "fossil methane" is a promising option in the near future.

The IEC 62282-8 series aims to develop performance test methods for power storage and buffering systems based on electrochemical modules (combining electrolysis and fuel cells, in particular reversible cells), taking into consideration both options of re-electrification and substance (and heat) production for the sustainable integration of renewable energy sources.

Under the general title "Energy storage systems using fuel cell modules in reverse mode", the IEC 62282-8 series consists of the following parts:

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- IEC 62282-8-101: Test procedures for the performance of solid oxide single cells and stacks, including reversible operation
- IEC 62282-8-102: Test procedures for the performance of single cells and stacks with proton exchange membrane, including reversible operation
- IEC 62282-8-103[1]: Alkaline single cell and stack performance including reversible operation
- IEC 62282-8-201[2]: Test procedures for the performance of power-to-power systems
- IEC 62282-8-202[3]: Power-to-power systems – Safety
- IEC 62282-8-3xy (all parts): Power-to-substance systems

As a priority dictated by the emerging needs for industry and the opportunities for technological development, IEC 62282-8-101, IEC 62282-8-102 and IEC 62282-8-201 were initiated jointly.

This document is the first of the IEC 62282-8-3xy series.

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1 Under consideration.

2 Second edition under preparation. Stage at the time of publication: IEC CDV 62282-8-201:2023.

3 Under consideration.

FUEL CELL TECHNOLOGIES –

Part 8-301: Energy storage systems using fuel cell modules in reverse mode – Power-to-methane energy systems based on solid oxide cells including reversible operation – Performance test methods

1 Scope

This part of IEC 62282 specifies performance test methods of power-to-methane systems based on solid oxide cells (SOCs). Water, CO_2, and electricity are supplied to the system to produce methane and oxygen.

This document is not intended to be applied to solid oxide fuel cell (SOFC) cell/stack assembly units for power generation purposes only, since these are covered in IEC 62282-7-2. In addition, the test methods for SOC cell/stack assembly units including reversible operation (without any methanation reactor) are already described in IEC 62282-8-101. Users can substitute the selected test methods of this document with the equivalent test methods given in IEC 62282-8-101 (solid oxide electrolysis cell (SOEC) to produce H_2 only as well as SOFC operation mode and reversible mode) and in IEC 62282-7-2 (SOFC mode only).

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This document covers two types of processes as shown in Figure 1:

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- Case 1: Steam and CO_2 are introduced into the SOC (co-electrolysis process), and the product gas (mainly, H_2 + CO) is supplied to a methanation reactor (catalytic reactor);

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- Case 2: Steam is introduced into the SOC to generate H_2, which is supplied into a methanation reactor with CO_2.

Besides these two cases, the methanation catalyst can be integrated within the SOC, but this case is not within the scope of this document. This document provides, for testing systems, information on instruments and specifies measurement methods to test the performance of SOC cell/stack assembly units and of the methanation reactor for energy conversion purposes. To produce CH_4 from water and CO_2, the SOC is operated in electrolysis mode (solid oxide electrolysis cell (SOEC)). The SOC can be operated either in fuel cell mode (SOFC) or in reversible operation mode or both. In this document, the system is considered not to have components which store electricity, fluids, or heat.

This document is intended to be used for data exchanges in commercial transactions between the system manufacturers and customers. Users of this document can selectively execute test items suitable for their purposes from those described in this document.

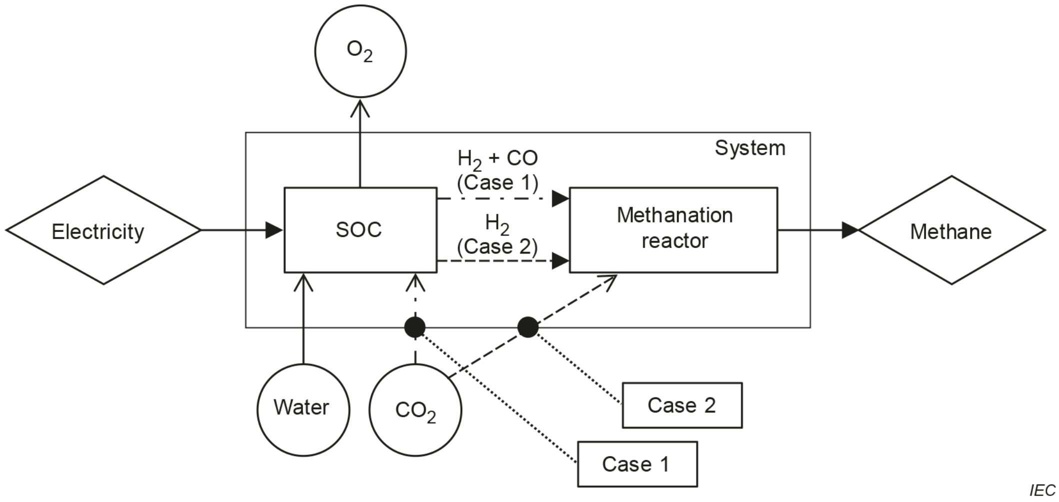

Figure 1 – Process schematic of the scope of IEC 62282-8-301

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 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*

IEC 62282-7-2:2021, *Fuel cell technologies – Part 7-2: Test methods – Single cell and stack performance tests for solid oxide fuel cells (SOFC)*

IEC 62282-8-101:2020, *Fuel cell technologies – Part 8-101: Energy storage systems using fuel cell modules in reverse mode – Test procedures for the performance of solid oxide single cells and stacks, including reversible operation*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 1: General principles and requirements*

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

ISO 6141, *Gas analysis – Contents of certificates for calibration gas mixtures*

ISO 6142-1, *Gas analysis – Preparation of calibration gas mixtures – Part 1: Gravimetric method for Class I mixtures*

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 methods – Part 7: Thermal mass-flow controllers*

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IEC 62282-8-301:2023
https://standards.iteh.ai/catalog/standards/sist/4d60a205-d53e-42b6-b089-51559f61cbdd/iec-62282-8-301-2023

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

ISO 6975, *Natural gas – Extended analysis – Gas-chromatographic method*

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 10101 (all parts), *Natural gas – Determination of water by the Karl Fischer method*

ISO 11541, *Natural gas – Determination of water content at high pressure*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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3.1.1
active electrode area
effective electrode area
geometric area of the electrode where the electrochemical reaction takes place

Note 1 to entry: Usually this corresponds to the smaller of the two areas of negative electrode or positive electrode.

Note 2 to entry: Area perpendicular to the ionic current flow, usually expressed in m^2 or cm^2.

[SOURCE: IEC 62282-8-101:2020, 3.1.1]

3.1.2
additional gas
gas added to the product gas from the negative electrode for the reaction in the methanation reactor

Note 1 to entry: For Case 2 in Figure 1, the additional gas is CO_2.

Note 2 to entry: For Case 1 in Figure 1 (co-electrolysis mode), CO_2 or H_2 or both can be added to convert the product gas from the negative electrode into CH_4 efficiently.

3.1.3
area-specific resistance
ASR
internal resistivity of any component of a cell or a stack, including the change of potential due to the electrochemical reaction

Note 1 to entry: It is normalized by the active electrode area and is expressed in $\Omega \cdot m^2$ or $\Omega \cdot cm^2$.

[SOURCE: IEC 62282-8-101:2020, 3.1.2]

3.1.4
catalyst
substance that accelerates a reaction without being consumed itself

[SOURCE: IEC 60050-485:2020, 485-01-01, modified – "electrochemical reaction" has been replaced by "reaction" and Note 1 and Note 2 have been deleted.]

3.1.5
cell
single cell
basic unit of a solid oxide cell

[SOURCE: IEC 62282-8-101:2020, 3.1.7, modified – "cell" has become a preferred term.]

3.1.6
cold state
state of a power-to-methane system at ambient temperature with no power input or output

Note 1 to entry: The cold state can come after the storage state during cooling-down of the system.

[SOURCE: IEC 60050-485:2020, 485-21-01, modified – "fuel cell power system" has been replaced by "power-to-methane system" and the Note to entry has been added.]

3.1.7
compression force
axial load
compressive load applied to the single cell or to the end plates of a planar SOC stack to ensure electric contact and gas tightness

Note 1 to entry: The compression force is in practice expressed in N.

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IEC 62282-8-301:2023
https://standards.iteh.ai/catalog/standards/sist/4d60a205-d53e-42b6-b089-51559f61cbdd/iec-62282-8-301-2023

[SOURCE: IEC 62282-8-101:2020, 3.1.7, modified – The preferred term "axial load" has become an admitted term and the admitted term "compression force" has become a preferred term.]

3.1.8
conditioning
preliminary step of treatment that is required to properly operate a SOC and is usually realized by following a protocol specified by the manufacturer

[SOURCE: IEC 62282-8-101:2020, 3.1.8, modified – The Note 1 to entry has been deleted.]

3.1.9
conversion of CO_2 into CH_4
catalytic conversion percentage of carbon dioxide into methane in the methanation reactor

3.1.10
conversion of H_2 into CH_4
catalytic conversion percentage of hydrogen into methane in the methanation reactor

3.1.11
current density
electric current per unit active area of the electrode

Note 1 to entry: The current density is expressed in A/m^2 or A/cm^2.

[SOURCE: IEC 60050-485:2020, 485-12-01, modified – "of the electrode" has been added and the domain has been deleted.]

3.1.12
electrode gas
gas present at the positive or negative electrode

Note 1 to entry: Electrode gases can be reactants, products or inert gas.

[SOURCE: IEC 62282-8-101:2020, 3.1.14]

3.1.13
interconnector
interconnect
electronically conductive and gas-tight component connecting single cells in a stack

[SOURCE: IEC 62282-8-101:2020, 3.1.4, modified – "electronically" has been added and the Notes to entry have been deleted.]

3.1.14
methanation reactor
catalytic reactor which converts CO_2, CO, and H_2 into CH_4

3.1.15
negative electrode
electrode at which fuel (reductant) gas is consumed or produced

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Note 1 to entry: In the case of electrolysis mode with an oxide-ion conducting electrolyte such as yttria-stabilized zirconia in a SOC, steam is reduced to produce hydrogen or a mixture of steam and CO_2 is reduced to produce H_2 + CO.

Note 2 to entry: In the case of electrolysis mode for a proton conducting SOC, the negative electrode gas is hydrogen or inert gas or both (Case 2 in Figure 1) or a mixture of hydrogen, CO_2 and inert gas (Case 1, co-electrolysis).

IEC 62282-8-301:2023
https://standards.iteh.ai/catalog/standards/sist/4d60a205-d53e-42b6-b089-51559f61cbdd/iec-62282-8-301-2023

[SOURCE: IEC 62282-8-101:2020, 3.1.19, modified – "(reductant)" has been added and the three Notes to entry have been replaced with two new Notes to entry.]

3.1.16
positive electrode
electrode at which oxygen is consumed or produced

Note 1 to entry: In the case of electrolysis mode for an oxide-ion conducting SOC, the positive electrode gas is usually air to carry the generated oxygen.

Note 2 to entry: In the case of electrolysis mode for a proton conducting SOC, the positive electrode gas is steam or a mixture of steam and inert gas to carry the generated oxygen.

[SOURCE: IEC 62282-8-101:2020, 3.1.21, modified – The three Notes to entry have been replaced with two new Notes to entry.]

3.1.17
protection gas
mixture of hydrogen and inert gas (usually argon or nitrogen) to protect the transition metal-containing negative electrodes of the SOC and the catalyst in the methanation reactor from being re-oxidized in case of abnormal operating conditions (e.g. electrode gas interruption, emergency stop of the test station)

3.1.18
rated conditions
recommended operation conditions (e.g. current, power) as specified by the manufacturer, at which the SOC system has been designed to operate

3.1.19
reversible mode
regenerative mode
operation mode of a solid oxide cell which alternates between fuel cell mode and electrolysis mode (Re-SOC)

Note 1 to entry: The term "reversible" in this context does not refer to the thermodynamic principle of an ideal process.

[SOURCE: IEC 62282-8-101:2020, 3.1.26]

3.1.20
shutdown time
time required for shutdown from the rated state to the cold state

Note 1 to entry: The shutdown time is expressed in s, min, or h.

3.1.21
shutdown energy
total energy input during shutdown from the rated state to the cold state

Note 1 to entry: The shutdown energy is expressed in kJ.

3.1.22
solid oxide cell
SOC
electrochemical cell composed of three functional elements (negative electrode, electrolyte and positive electrode)

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[SOURCE: IEC 62282-8-101:2020, 3.1.28, modified – "based on ceramic oxide materials" and the three Notes to entry have been deleted.]

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3.1.23
solid oxide electrolysis cell
SOEC
SOC operated in electrolysis mode

[SOURCE: IEC 62282-8-101:2020, 3.1.29, modified – "i.e. reversed fuel cell mode" and the three Notes to entry have been deleted.]

3.1.24
solid oxide fuel cell
SOFC
SOC operated in fuel cell mode

[SOURCE: IEC 62282-8-101:2020, 3.1.30, modified – Note 1 to entry has been deleted.]

3.1.25
space velocity
quotient of the entering volumetric flow rate of the reactants divided by the volume of the catalyst bed

Note 1 to entry: The space velocity is expressed in 1/s.

3.1.26
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

[SOURCE: IEC 62282-7-2:2021, 3.1.9]

3.1.27
stack
assembly of cells, interconnectors, cooling plates, manifolds and a supporting structure

[SOURCE: IEC 60050-485:2020, 485-06-01, modified – The first preferred term "fuel cell stack" has been deleted, "separators" has been replaced by "interconnectors" and "that electrochemically converts, typically, hydrogen-rich gas and air reactants to DC power, heat and other reaction products" has been deleted.]

3.1.28
start-up time
time required for start-up from the cold state to the rated state

Note 1 to entry: The start-up time is expressed in s, min, or h.

3.1.29
start-up energy
total energy input during start-up from the cold state to the rated state

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Note 1 to entry: The start-up energy is expressed in kJ.

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3.1.30
storage state
state of a power-to-methane system being non-operational and possibly requiring, under conditions specified by the manufacturer, the input of thermal and electric energy, or an inert atmosphere, or any combination thereof, in order to prevent deterioration of the components and to energize the control systems

[SOURCE: IEC 60050-485-21-06, modified – "fuel cell power system" has been replaced by "power-to-methane system" and “to energize the control systems" has been added.]

3.1.31
sweep gas
gas supplied to the positive electrode compartment of the SOC to carry the generated oxygen

Note 1 to entry: Air is frequently used as the sweep gas in the case of an oxide-ion conduction SOC to carry generated O_2 gas. For a proton-conducting SOC, steam or a mixture of steam and inert gas is supplied to carry the generated O_2.

3.1.32
test input parameter
TIP
parameter whose values can be set in order to define the test conditions of the test system including the operating conditions of the test object

[SOURCE: IEC 62282-8-101:2020, 3.1.33, modified – The Note 1 to entry has been deleted.]

3.1.33
test output parameter
TOP
parameter that indicates the response of the test system/test object as a result of variation of TIPs

[SOURCE: IEC 62282-8-101:2020, 3.1.34, modified – The Note 1 to entry has been deleted.]

3.2 Abbreviated terms and symbols

3.2.1 Abbreviated terms

AC alternating current
ASR area-specific resistance
CE current efficiency
DC direct current
DR degradation rate
FT Fischer Tropsch
GWP global warming potential
HHV higher heating value
LHV lower heating value
P2G power-to-gas
SOC solid oxide cell
SOEC solid oxide electrolysis cell
SOFC solid oxide fuel cell
Re-SOC reversible solid oxide cell
STP standard temperature and pressure
SV space velocity
TIP test input parameter
TOP test output parameter

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3.2.2 Symbols

Table 1 lists the symbols and units that are used in this document.

Table 1 – Symbols

Symbol	Definition	Unit(s)
A_{active}	Active (geometric) area of the cell/stack electrode(s)	m^2, cm^2
$\boldsymbol{c}$	**Concentration**	
c_i	Molar concentration of component i	mol/m^3
$\boldsymbol{C_p}$	**Heat capacity**	
$C_{p,\mathrm{c}}$	Heat capacity of the heat transfer fluid at standard pressure	J/(kg · K)
$C_{p,i}$	Heat capacity of component i at standard pressure	J/(kg · K)
$\boldsymbol{E}$	**Energy**	
$E_{\mathrm{el,in}}$	Electric energy input to the system	kJ
$E_{\mathrm{el,out}}$	Electric energy output from the system	kJ
$E_{\mathrm{sp,CH4}}$	Specific electric energy consumed for producing a unit volume of CH_4	kJ/m^3