



Pre-normative research on safe indoor use of fuel cells and hydrogen systems

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D6.1 Report on recommendations for RCS

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0	Randy Dey 27/10/2014	CCS	Coordinator, AL
1	Randy Dey Guy Dang-Nhu Daniele Baraldi Eveline Weidner Jan der Kinderen 31/10/2014	CCS	Coordinator, AL.
2	Randy Dey Guy Dang Nhu Volodymyr Shentsov Vladimir Molkov 24/11/2014	CCS	Coordinator, AL
3	Randy Dey Guy Dang Nhu Vladimir Molkov 26/11/2014	CCS	Coordinator, AL
4	Randy Dey Guy Dang Nhu Vladimir Molkov 30/11/2014	CCS	Coordinator, AL
5	Randy Dey Guy Dang Nhu Vladimir Molkov Jan der Kinderen Boris Chernyavskiy and Dmitriy Makarov 03/12/2014	CCS	Coordinator, AL
6	Randy Dey Guy Dang Nhu 05/12/2014	CCS	Coordinator, AL
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1 Executive summary

1.1 Summary of deliverable content and initial objectives

The objective of this D6.1 deliverable report is to study the findings of Hyindoor project and then to identify and categorize regulations, codes and standards (RCS) recommendations concerning the safe indoor use of fuel cells and hydrogen systems and to propose a roadmap for bringing these recommendations to international bodies. The report represents the consensus of the Hyindoor group regarding RCS recommendations.

1.2 Partners involved

All partners were involved in this Work package.

1.3 Relation with other WPs / Tasks

The results of the work of WP2-5 of the project were taken into account in this report. WP6 worked in conjunction with WP1 Safety objectives and strategies specified in existing RCS for selected configurations and summarized the findings of WP2-Dispersion and accumulation, WP3-Vented deflagrations, WP4-Hydrogen jet-fire and WP5-Safety strategies and guidelines (including deployment of hydrogen sensors) to identify RCS recommendations.

2 Introduction

Hydrogen energy applications often require that systems be used indoors (e.g., industrial trucks for materials handling in a warehouse facility, fuel cells located in a room, or hydrogen stored and distributed from a gas cabinet). It may also be necessary or desirable to locate some hydrogen system components/equipment in indoor or outdoor enclosures for security or safety reasons to isolate them from the end-user and the public, or from weather conditions.

Use of hydrogen in confined environment requires detailed assessment of hazards and associated risks, including potential risk prevention and mitigation features. The release of hydrogen can potentially lead to the accumulation of hydrogen and the formation of a flammable hydrogen-air mixture.

Hyindoor is a European Project aimed at developing safety design guidelines and engineering tools to prevent and mitigate hazardous consequences of hydrogen release in confined environments. Closing knowledge gaps is critical to this effort in 3 main areas:

- Hydrogen release conditions and accumulation,
- Vented deflagration
- Jet fire and under-ventilated flame regimes (e.g., extinguishment or oscillating flames and steady burns).

For each phenomenon, the release position/conditions, the number, size and location of the openings in the room/enclosure of some given size, and the type of ventilation can significantly influence the prevention/mitigation strategy.

Each of these phenomena has been subject to analytical, experimental and numerical analysis within a dedicated work package.

They each have shared state of the art information in order to prioritise the research objectives. Existing analytical and numerical models were initially used to facilitate the formulation of the test program, while the experimental results were subsequently used to validate and improve the models and identify RCS recommendations where appropriate.

The final D6.1 report on RCS recommendations collects results from all Hyindoor Work Packages, builds consensus within the group and presents them in a comprehensive report. The objective is to summarize the regulations, codes and standards (RCS) findings of the Hyindoor project and to batch them into categories such as ventilation, limitation of over-pressure and other recommendations to support RCS initiatives. Also it develops a path forward for bringing these recommendations to the international RCS bodies (e.g. ISO, IEC).

3 RCS for the Hyindoor configurations

The intention of this task is to identify the RCS recommendations for the safe indoor use of fuel cells and hydrogen systems. A variety of configurations have been selected by the Hyindoor project. The report will identify possible improvements derived from the work of the test program and guidelines report (including deployment of hydrogen sensors). Briefly, here is a description of the five configurations that were selected at the beginning of the Hyindoor project regarding industrial applications.

3.1 Forklift vehicle operation and refuelling in a warehouse

The RCS requirements of fuel cell forklift vehicle applications will eventually be covered by IEC 62282-4-101:2014 Ed 1.0. Presently, the IEC/TC 105 WG6 is actively working on IEC 62282-4-102 Ed 1.0. Any Hyindoor recommendations could feed into the next revision of the standard.

It should be noted that IEC 62282-5-1:2012 Edition 2.0 includes an informative annex that covers the additional shock and vibration requirements of portable fuel cells used in specialty vehicles such as forklifts for battery replacement.

The indoor refuelling operation in a warehouse will eventually be covered in ISO/WDTR 19880 - 1

As the scope of the TR does not cover indoor refuelling, the ISO/TS 20100:2008 requirements and its Annex A should be considered.

3.2 Operation of a fuel cell in a room where other activities are performed (e.g. providing back-up power to a data centre or power supply to noiseless movie camera and auxiliary equipment)

In the case of the fuel cell equipment, it should meet all the requirements of the product standard. Safety of stationary fuel cell power systems is covered in IEC 62282-3-100:2012, Edition 1.0.

Presently, IEC/TC 105 WG 12 is actively working on small stationary fuel cell power systems with combined heat and power output which will be covered in IEC 62282-3-400 Ed 1.0.

The installation requirements are covered by IEC 62282-3-300:2012 Edition 1.0.

3.3 Storage of hydrogen in a dedicated room (supplying hydrogen to a fuel cell)

The pressure vessels used for the storage of hydrogen for stationary applications are intended to be covered by ISO/CD 19884 Ed 1 which is under development. Compliance to this International Standard when published will ensure the safety of the storage containers themselves.

In terms of standards for hydrogen components such as TPRD, the pressure reduction system, piping, etc and indeed for installation requirements themselves, there is currently no international standard that covers these items. In the meantime, the ISO/TS 20100:2008 requirements and its Annex A should be considered.

3.4 Storage of hydrogen and distribution to a fuel cell in a cabinet or a larger container (located outdoors or indoors)

This application is a combination of the requirements of indoor hydrogen storage and fuel cell, which are covered in Section 2.2 and 2.3 above.

In addition, ISO 22734-1:2008 covers safety requirements for hydrogen generators using water electrolysis for Industrial & Commercial applications while ISO 22734-2:2011 is for Residential applications.

3.5 Use of a portable fuel cell generator with its hydrogen supply indoors

The RCS requirements of portable fuel cell generators are defined in IEC 62282-5-1:2012, Edition 2.0.

General note: If restrictions of use are to be suggested based on the findings of Hyindoor (e.g. minimum ventilation requirements to be specified for indoor applications), they should be included in the Marking section or in the Operation and Maintenance manual.

4 Short list of related RCS

4.1 List of Active RCS

WG	Work items
ISO/TC 197 WG 15	ISO/CD 19884 Ed 1. Gaseous Hydrogen — Cylinders and tubes for stationary storage Committee draft stage
ISO/TC 197 WG 16	ISO/DTR 15916 Ed 2. <i>Basic considerations for the safety of hydrogen systems</i> Draft Technical report stage
ISO/TC 197 WG 24	ISO/WDTR 19880 - 1 Gaseous Hydrogen Fueling stations – General Requirements Working draft stage
IEC/TC 105 WG 4	IEC 62282-3-200 Ed 2.0. Fuel cell technologies - Part 3-200: Stationary fuel cell power systems – Performance test methods CDV/Editing check
IEC/TC 105 WG 4	IEC 62282-3-201 Ed 2.0. Fuel cell technologies – Part 3-201: Stationary fuel cell power systems – Performance methods for small fuel cell power systems. Committee stage
IEC/TC 105 WG 12	IEC/ 62282-3-400 Ed 1.0. Fuel cell technologies – Part 3-400: Stationary Fuel Cell Power Systems – Small stationary Fuel Cell Power Systems with combined heat and power output. Committee stage
IEC/TC 105 WG 6	IEC 62282-4-102 Ed 1.0. Fuel cell technologies – Part 4-102: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Performance test methods for electrically powered industrial trucks Committee stage

4.2 List of Published RCS

#	Item
ISO/TR 15916:2004	Basic considerations for the safety of hydrogen systems
ISO/TS 20100:2008	Gaseous hydrogen — Fuelling stations
ISO 22734-1:2008	Hydrogen generators using water electrolysis process — Part 1: Industrial and commercial applications
ISO 22734-2:2011	Hydrogen generators using water electrolysis process — Part 2: Residential applications Edition 1
ISO 26142:2010	Hydrogen detection apparatus — Stationary applications
IEC 62282-2:2012 Edition 2.0	Fuel cell technologies – Part 2: Fuel cell modules
IEC 62282-3-100:2012 Edition 1.0	Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety
IEC 62282-3-200:2011 Edition 1.0	Fuel cell technologies - Part 3-200: Stationary fuel cell power systems – Performance test methods
IEC 62282-3-201:2013 Edition 1.0	Fuel cell technologies - Part 3-201: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems
IEC 62282-3-300:2012 Edition 1.0	Fuel cell technologies - Part 3-300: Stationary fuel cell power systems – Installation
IEC 62282-4-101:2014 Edition 1.0	Fuel cell technologies – Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety of electrically powered industrial trucks
IEC 62282-5-1:2012 Edition 2.0	Fuel cell technologies - Part 5-1: Portable fuel cell power systems – Safety

For a complete list of Active and Published International RCS, see Annex 1 and Annex 2.

4.3 Regulations

Finally, there are a few regulations that apply to all the scenarios described above. They include the following:

- DIRECTIVE 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres,
- DIRECTIVE 94/9/EC of the European Parliament and of the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres; and

5 RCS recommendations

Early in the project, a report was prepared on safety objectives and strategies specified in existing RCS for the selected configurations that identified RCS issues and the specific information that the test program can address in the Hyindoor project. The Hyindoor scientific results produced useful inputs on different topics which are covered in the public Guidelines report (D5.1) as intended in the description of work for Hyindoor and it also produced some interesting RCS recommendations.

As part of Task 6.1, WP6 prepared a list of relevant active and published standards. See Annex 1 and Annex 2 updated at the time of this report. It also worked in conjunction with WP1 that produced a first report at the beginning of the project and continued to update it until recently when this report was released to keep the members of Hyindoor informed of the current RCS activities. There was a strong interaction between WP6 and all other work packages (WP2 to WP5) that facilitated the progress towards arriving at the present D6.1 report.

This D6.1 report covers the identification and categorization of the RCS recommendations. In summary, there are eighteen RCS recommendations intended as main consideration in RCS work including one item (#18) that is being proposed to be used optionally.

5.1 Main RCS recommendations

Following recommendations are based on phenomena discovered during Hyindoor project whose aim is to disseminate them to standard development organisations (SDO) and international bodies.

The main RCS recommendations are listed in the following sections:

5.1.1 Ventilation

This section covers recommendations regarding the implementation of ventilation for preventing the formation of an explosive atmosphere, or for limiting the hydrogen concentration, in the event of a hydrogen leak release.

- **RCS recommendation #1. Effect of wall thickness supporting the ventilation vent:** the thicker the wall, the more the concentration inside the vessel.

The thickness of the wall supporting the ventilation vent should be as small as possible. In the case that walls of different thickness are available, the obvious choice for the vent location should be on the thinner wall.

- **RCS recommendation #2. Effect of horizontal ducts:** should be avoided

The use of horizontal duct should be avoided or limited. When it is necessary to install a horizontal duct in the design of the venting system it should be taken into account that this additional element decreases the effect of the vent on the concentration field inside the enclosure.

- **RCS recommendation #3. Effect of position of vent:** on the wall preferred to roof

With respect to the orientation of vents (roof v/s side wall) generally roof vents are not as efficient as wall vents of the same size.

- **RCS recommendation #4. Effect of rain cover:** should be avoided

The use of rain cover should be avoided or limited. When it is necessary to install a rain cover in the design of the venting system it should be taken into account that this additional element decreases the effect of the vent on the concentration field inside the enclosure.

- **RCS recommendation #5. Height of a single vent position: should preferably be located at the top of a wall**

The vent position should be placed in the upper part of the facility and the upper limit of the vent should be placed at the level of the ceiling as much as possible.

- **RCS recommendation #6. Obstruction in from of openings: should be avoided**

Obstructions to the vent should be avoided or limited.

- **RCS recommendation #7. Vent shape: vents bigger in height than width preferred**

Vents of the same area with higher vertical dimension should be selected compared to vents with a wider horizontal dimension.

In summary, vent thickness, the use of roof covers and ducts, the vent position, and the vent shape have an effect on the concentration field inside an enclosure and therefore those parameters should be taken into account in the design of the venting system.

- **RCS recommendation #8. Ventilation system: calculate hydrogen concentration in an enclosure with one vent using passive ventilation model**

Deliverable 5.1 provides the nomogram for calculation of maximum (conservative) hydrogen concentration for the steady-state release in enclosure with one vent. Passive ventilation model is published and validated against CEA experiments. Previously applied “natural” model under-predicts twice low hydrogen concentrations and over-predicts rich concentration twice.

- **RCS recommendation #9. Ventilation system: calculate hydrogen concentration in an enclosure with two-openings natural ventilation system**

Deliverable 5.1 provides engineering modelling approach for calculation of maximum (conservative) hydrogen concentration at the steady-state in enclosure with two (or more) vent(s) located at two different heights. Two-openings natural ventilation model is published and validated against several open experiments available in scientific literature (e.g. CEA experiments).

- **RCS recommendation #10. Ventilation – numbers and location**

Multiple vents at different heights on opposite walls are preferable to one vent of the same area.

- **RCS recommendation #11. Ventilation – distribution of vents**

Locate vents as low at the bottom and as high at the top as possible.

- **RCS recommendation #12. Mitigate hydrogen build-up when passive/natural ventilation is not effective enough**

When passive/natural ventilation is not effective enough, other efficient ways can be investigated like: mechanical/forced ventilation, devices limiting release flow rates or detection devices.

5.1.2 Limitations of over-pressure

This section covers recommendations regarding the implementation of venting devices for limiting the overpressure developed in the event of a hydrogen release as a result either of the Pressure Peaking Phenomenon (PPP) or of the deflagration of a flammable hydrogen-air mixture.

- **RCS recommendation #13. Enclosure with high pressure hydrogen equipment: Pressure Peaking Phenomenon (PPP) in enclosures with low ventilation level and high release**

flow rate

Deliverable 5.1 provides published and validated within Hyindoor technique to calculate the overpressure inside vented enclosure with hydrogen release due to PPP. PPP is recently revealed phenomenon characteristic only for gases lighter than air and particularly pronounced for hydrogen. Structural strength of civil structures 10-20 kPa should not be exceeded. PPP can be avoided either by increase of vent(s) area or by decrease of hydrogen leak rate, e.g. by reduction of releasing device diameter or introduction of a flow restrictor in pipework.

- **RCS recommendation #14. Deflagration mitigation: limit hydrogen inventory in enclosure to exclude structural damage (such as warehouse)**

Deliverable 5.1 presented the analytical thermodynamic model, which was validated against experimental data published elsewhere. The validated model establishes the upper limit for hydrogen mass allowed to be released (stored) in an enclosure of known volume without causing overpressure above 10 kPa in case of its combustion. This safety strategy is conservative and usually applied to enclosures with poor, not specified or not specially provided ventilation. The limit of stored hydrogen mass related to the enclosure volume is 0.26 g/m³. (or averaged hydrogen concentration by volume in enclosure should be below 0.3 %, which is by more than order of magnitude below Lower Explosion Limit (LFL) of 4 %. Below this limit hydrogen-air deflagration of the released inventory would not produce structural damage to load bearing members (minor damage at level of windows breakage could be expected). This strategy improves life safety by exclusion of civil structure collapse and applicable where possible. If the limitation of inventory is not possible other safety measures should be applied, e.g. passive or forced ventilation to prevent flammable mixture formation, or mitigation of deflagration by venting technique.

- **RCS recommendation #15. Vented deflagration: use updated correlation for vent sizing of enclosures fully filled by hydrogen–air mixture, and new correlation for vent sizing of enclosures partially filled by flammable hydrogen-air mixture**

New techniques for vent sizing developed as result of Hyindoor analytical and experimental studies is reported in deliverable 5.1. These two correlations cover not only scenarios with uniform mixture occupying the entire enclosure volume but cases of uniform flammable hydrogen-air layer and non-uniform gradient layers of hydrogen in air (validated in D3.4).

5.1.3 Other

This section covers recommendations regarding jet-fires, hydrogen sensors and optional use of flow restrictors.

- **RCS recommendation #16. Jet fire: use the universal correlation for jet fire length to calculate three deterministic separation (hazardous) distances**

Deliverable 5.1 provides a methodology for flame length calculation and determination of three deterministic separation distances.

- **RCS recommendation #17. Sensors, effect of poisoning**

The selection and use of hydrogen sensors was studied.

As many types of sensor platforms are commercially available, the optimal choice of sensor for a particular application is not straightforward.

ISO 26142 is specific to hydrogen sensors, providing performance requirements and test methods for stationary hydrogen detection apparatus. This standard covers situations where the user desires the ability to detect hydrogen leaks and monitor hydrogen concentrations relevant to safety. This standard is primarily intended for hydrogen sensors at vehicle refuelling stations, but may also be applied to other stationary installations where the detection of hydrogen is required.

Based on the tests performed for Hyindoor, the exposure time of 1h, coupled with the specification of

performing the tests in dry air, may not accurately reflect all deployment conditions. Depending on the application, the concentration level of HMDS could be raised, as 10 ppm may be lower than the exposure level a sensor could experience. The use of lubricants or sealants in warehouses or other work environments may lead to higher concentration of siloxanes.

The tests also showed that the effect of poisons is often transient. In some cases it was found that an effect can be seen in the cycle following the exposure to the poison, but recovered after a few hours exposure to clean air. The standard states at present that the evaluation of the effect of the poison should be analyzed immediately following the exposure to the poison. In light of the experiments performed, this test method could be revised. Our recommendation is to evaluate the effect of the poison both immediately after exposure and after three (or more) cycles with air/hydrogen.

- **RCS recommendation #18. Use of flow restrictors to be used optionally**

Generally, for outdoor and indoor use of hydrogen, flow restrictors on the pipe are good intrinsically safe design measure. Indeed, by limiting the maximum potential flow of a hydrogen release downstream of the restriction, it limits the potential effects: thermal radiation due the jet flame in case of immediate ignition and size of the cloud and corresponding over pressure effects in case of delayed ignition. The safety benefits are maximized when the flow restriction is located at the nearest point of the main H₂ storage (sources) and if possible upstream of all components, with the minimum number of connections upstream the flow restrictions.

For indoor application the flow restriction could also limit the likelihood and possibly prevent completely the risk of accumulation of Hydrogen above the Lower Explosion Limit (LEL) within the confined space.

When the storage is located outside a building and the hydrogen equipment & installation inside (e.g. dispenser devices in warehouses for H₂ forklift trucks), it is strongly recommended to put the flow restriction on the pipe outside the building before entering inside the warehouse.

The flow restriction must be appropriately designed for the use considering the maximum needed process flow rate: for example 60g/s for cars or 120 g/s for buses according to SAE J2601. This item should take into account all the phases of the life cycle, Nitrogen purging for example. The ventilation should be designed in order to limit or prevent accumulation of hydrogen above LEL into the confined space.

The flow restriction could consist of a disk with a hole inside the H₂ pipe located at a fitting (orifice plate).

The disk can be welded. A milli=metric needle valve can also be used. In such a case the valve should be locked-out, so it shall not be possible to change inadvertently the set point of the valve.

Such a flow restriction could also be used on safety system as thermally activated Pressure Relief Device in order to minimize the size of the jet flame in case of release. But in this case, the sizing should be a compromise between the necessary emptying time of the storages (in case of fire) and the flame length generated by the release.

Example of the impact of the use of a restriction, the case of 700 bar storage with a piping of 10 mm and a restriction of 1 mm has been worked out to a more practical example, the forklift truck with a storage tank of 700bar. A pipeline rupture of 10 mm at 700 bar to atmospheric gives an hydrogen flow of 2.69 kg/sec. Using a restriction of 1 mm diameter reduces this flow to 0.027 kg/sec with a maximum flame length of 4.4 meter. Current fuel cell systems operate close to atmospheric pressure (e.g. forklift truck). So, even this reduced amount of hydrogen release results in a potential hydrogen input power to the fuel cell of 3900 kW (HHV: 286 MJ/kmol). With a fuel cell efficiency of 55% gives this an electrical power 1500 kWe. If the storage tank is emptied to an amount of 10 bar, the release of hydrogen falls down to 0.00048 kg/sec which gives a potential of 38 kWe.

An average forklift truck needs roughly 7-15 kWe at maximum power (speed plus lifting). The hydrogen release with a restriction at a nearly empty storage is still 3-5 times the power request of the forklift truck. So it means that this restriction of 0.1 mm can be reduced even further. This example gives a clear view of the benefits of the use of a restriction. While it is clear that sometimes due to technical requirements one cannot add or can only use a wide restrictor, it is an important safety feature that is easily added.

6 Proposed path forward

In this section of the D6.1 report, a path forward on how the RCS recommendations may be integrated into ongoing or new RCS activities is proposed.

It is being proposed that the identified RCS recommendations be forwarded to the Secretariat of the relevant ISO or IEC technical committees for consideration by the technical committee and relevant working groups.

NOTE: Although some pathways are being proposed in the report, it will not be the work of Hyindoor to implement these RCS recommendations.

6.1 Recommendations to be forwarded to the Secretariat of ISO/TC 197 – Hydrogen Technologies

All the recommendation #1-18 of section 5 of this report may be considered and specifically RCS recommendation #17 pertaining to hydrogen sensors shall be forwarded to:

Secretariat: SCC
Secretary: Mr. Jim Ferrero
Chairperson: Dr. Andrei Tchouvelev
ISO Central Secretariat contact: Mr Andrew Dryden

The main standard for recommendation #17 is:

ISO 26142:2010

Hydrogen detection apparatus — Stationary applications

For all the other recommendations, the following active and published standards may be considered by the technical committee:

Active:

ISO/TC 197, WG 15

ISO/CD 19884 Ed 1. Gaseous Hydrogen — Cylinders and tubes for stationary storage
Committee draft stage

ISO/TC 197, WG 16

ISO/DTR 15916 Ed 2. *Basic considerations for the safety of hydrogen systems*
Draft Technical report stage

ISO/TC 197, WG 24

ISO/WDTR 19880 - 1 Gaseous Hydrogen Fueling stations – General Requirements
Working draft stage

Published:

ISO/TR 15916:2004

Basic considerations for the safety of hydrogen systems

ISO/TS 20100:2008

Gaseous hydrogen — Fuelling stations

ISO 22734-1:2008

Hydrogen generators using water electrolysis process — Part 1: Industrial and commercial applications

ISO 22734-2:2011

Hydrogen generators using water electrolysis process — Part 2: Residential applications Edition 1

ISO 26142:2010

Hydrogen detection apparatus — Stationary applications

6.2 Recommendations to be forwarded to the Secretariat of CEN/TC268, WG5 – Hydrogen technologies

All the recommendation #1-18 of section 5 of this report may be considered and specifically RCS recommendation #17 pertaining to hydrogen sensors shall be forwarded to:

Secretariat: AFNOR

Secretary: Ms. Laurie Jardel

Chairperson: Mr. Herve Barthelemy

6.3 Recommendations to be forwarded to the Secretariat of IEC/TC 105 - Fuel Cell technologies.

All the recommendation #1-18 (except #17) of section 5 of this report may be considered and shall be forwarded to:

Secretariat: DIN

Secretary: Mr. Wolfgang Winkler

Chairperson: Mr Fumio Ueno

ISO Central Secretariat contact: Mr Charles Jacquemart

For all the other recommendations, the following active and published standards may be considered by the technical committee:

Active:**IEC/TC 105 WG 4**

IEC 62282-3-200 Ed 2.0. Fuel cell technologies - Part 3-200: Stationary fuel cell power systems – Performance test methods

CDV/Editing check

IEC/TC 105 WG 4

IEC 62282-3-201 Ed 2.0. Fuel cell technologies – Part 3-201: Stationary fuel cell power systems – Performance methods for small fuel cell power systems.

Committee stage

IEC/TC 105 WG 12

IEC/ 62282-3-400 Ed 1.0. Fuel cell technologies – Part 3-400: Stationary Fuel Cell Power Systems – Small stationary Fuel Cell Power Systems with combined heat and power output.

Committee stage

IEC/TC 105 WG 6

IEC 62282-4-102 Ed 1.0. Fuel cell technologies – Part 4-102: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Performance test methods for electrically powered industrial trucks

Committee stage

Published:**IEC 62282-2:2012**

Edition 2.0

Fuel cell technologies – Part 2: Fuel cell modules

IEC 62282-3-100:2012

Edition 1.0

Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety

IEC 62282-3-200:2011

Edition 1.0

Fuel cell technologies - Part 3-200: Stationary fuel cell power systems – Performance test methods

IEC 62282-3-201:2013

Edition 1.0

Fuel cell technologies - Part 3-201: Stationary fuel cell power systems – Performance test methods for small fuel cell power systems

IEC 62282-3-300:2012

Edition 1.0

Fuel cell technologies - Part 3-300: Stationary fuel cell power systems – Installation

IEC 62282-4-101:2014 Edition 1.0

Fuel cell technologies – Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety of electrically powered industrial trucks

IEC 62282-5-1:2012

Edition 2.0

Fuel cell technologies - Part 5-1: Portable fuel cell power systems – Safety

6.4 Regulations

Only after the respective technical committees accept the recommendations and the standards are revised, there should be an effort to have these revised standards be referred to in regulations (e.g. EU/PED or national).

7 Annexes

Annex 1: Complete list of Active International RCS

Annex 2: Complete list of Published International RCS

7.1 Annex 1

List of Active International RCS

WG	Work items	Scope
ISO/TC 197 WG 15	ISO/CD 19884 Gaseous Hydrogen — Cylinders and tubes for stationary storage Edition 1	The standard covers cylinders and tubes intended for the stationary storage of gaseous hydrogen of up to a maximum volume of 10 000 l and a maximum pressure of 110 MPa, of seamless metallic construction or of composite construction.
ISO/TC 197 WG 16	ISO/DTR 15916 <i>Basic considerations for the safety of hydrogen systems</i> Edition 2	This Technical Report provides guidelines for the use of hydrogen in its gaseous and liquid forms. It identifies the basic safety concerns and risks, and describes the properties of hydrogen that are relevant to safety. Detailed safety requirements associated with specific hydrogen applications are treated in separate International Standards.
ISO/TC 197 WG 24	ISO/WDTR 19880 - 1 Gaseous hydrogen fuelling stations – General requirements	This Technical Report specifies the design characteristics of public and non-public fuelling stations that dispense gaseous hydrogen used as fuel on board land vehicles of all types. This technical report specifies the minimum requirements for design characteristics and safety. This document addresses fuelling mainly for light duty hydrogen land vehicles, but the later standard will also encompass buses and fork-lift truck applications. Residential applications to fuel land vehicles and temporary demonstration fuelling stations are excluded from this Technical Report. The fuelling station (see Figure 1) may comprise of the following: <ul style="list-style-type: none"> - H2 supply - Delivery of hydrogen by pipeline, trucked in gaseous and/or liquid hydrogen; - On-site hydrogen generators using water electrolysis process or hydrogen generators using fuel processing technologies; - Liquid hydrogen storage; - Hydrogen purification systems, as applicable; - Compression - Gaseous hydrogen compression; - Pumps and vaporizers; - Gaseous hydrogen buffer storage; - Pre-cooling device; - Gaseous hydrogen dispensers.
IEC/TC 105 WG 4	IEC/CDV 62282-3-200 Fuel cell technologies – Part 3-200: Stationary Fuel Cell Power Systems – Performance test methods Edition 2.0	This part of IEC 62282 covers operational and environmental aspects of the stationary fuel cell power systems performance. The test methods apply as follows: <ul style="list-style-type: none"> - power output under specified operating and transient conditions; - electric and thermal efficiency under specified operating conditions; - environmental characteristics; for example, exhaust gas emissions, noise, etc. under specified operating and transient conditions. <p>This standard does not provide coverage for electromagnetic compatibility (EMC).</p> <p>This standard does not apply to small stationary fuel cell power systems with electric power output of less than 10 kW which are dealt with IEC 62282-3-201.</p> <p>Fuel cell power systems may have different subsystems depending upon types of fuel cell and applications, and they have different streams of material and energy into and out of them. However, a common system diagram and boundary has been defined for evaluation of the fuel cell power system (see Figure 1).</p> <p>The following conditions are considered in order to determine the system boundary of the fuel cell power system: <ul style="list-style-type: none"> - all energy recovery systems are included within the system boundary; - all kinds of electric energy storage devices are considered outside the system boundary; </p>

WG	Work items	Scope
		<ul style="list-style-type: none"> - calculation of the heating value of the input fuel (such as natural gas, propane gas and pure hydrogen gas, etc.) is based on the conditions of the fuel at the boundary of the fuel cell power system.
IEC/TC 105 WG 4	IEC/CD 62282-3-201 Fuel cell technologies – Part 3-201: Stationary Fuel Cell Power Systems – Performance methods for small fuel cell power systems Edition 2.0	<p>This part of IEC 62282 provides test methods for the electric/thermal and environmental performance of small stationary fuel cell power systems that meet the following criteria:</p> <ul style="list-style-type: none"> • output: nominal electric power output of less than 10 kW; • output mode: grid-connected/independent operation or stand-alone operation with single-phase AC output or 3-phase AC output not exceeding 1 000 V, or DC output not exceeding 1 500 V; <p style="text-align: center;">NOTE: The limit to 1 000 V comes from the definition for "low voltage" given in IEC 601-01-26.</p> <ul style="list-style-type: none"> • operating pressure: maximum allowable working pressure of less than 0,1 MPa (gauge) for the fuel and oxidant passages; • fuel: gaseous fuel (natural gas, liquefied petroleum gas, propane, butane, hydrogen, etc.) or liquid fuel (kerosene, methanol, etc.); • oxidant: air. <p>This standard covers fuel cell power systems whose primary purpose is the production of electric power and whose secondary purpose may be the utilization of by-product heat. Accordingly, fuel cell power systems for which the use of heat is primary and the use of by-product electric power is secondary are outside the scope of this standard.</p> <p>All systems with integrated batteries are covered by this standard. This includes systems where batteries are recharged internally or recharged from an external source.</p> <p>This standard does not cover additional auxiliary heat generators that produce thermal energy.</p>

WG	Work items	Scope
<p>IEC/TC 105 WG 12</p>	<p>IEC/CD 62282-3-400 Fuel cell technologies – Part 3-400: Stationary Fuel Cell Power Systems – Small stationary Fuel Cell Power Systems with combined heat and power output. Edition 1.0</p>	<p>This standard applies to small stationary fuel cell power systems serving as a heating appliance providing both electrical power and useful heat with or without a supplementary heat generator providing peak load function.</p> <p>This standard applies to fuel cell power systems that are intended to be permanently connected to the electrical system of the customer (end user). Connection to the mains directly (parallel operation) is also within the scope of this standard</p> <p>NOTE: Parallel operation is subject to the permission of the local electric power supply utility</p> <p>This standard is limited to gas and liquid fuelled fuel cell power systems that have a heat input based on lower heating value of less than 70 kW. For some regional applications the output electric power is limited. Specific limitations will be given in the annexes for individual countries.</p> <p>This standard applies to systems intended for operation on the following supplied input fuels:</p> <ul style="list-style-type: none"> - natural gas and other methane rich gases such as city gas; - fuels derived from oil refining (kerosene, liquefied petroleum gases, propane, and butane); - alcohols, (methanol, ethanol); - hydrogen <p>The following points also apply:</p> <ul style="list-style-type: none"> · The heat transfer fluid (heat output) shall be water or a mixture of water and additives to prevent corrosion and to prevent freezing. · The heat transfer fluid circuit (heat output) can be designed for open or sealed operation. · The maximum temperature of the heat transfer fluid (heat output) shall not exceed the regional limits shown in the regional annexes. · The maximum pressure of the heat transfer fluid (heat output) circuit shall not exceed the regional limits shown in the regional annexes. · The maximum pressure of the potable water circuit, if installed, shall not exceed the regional limits shown in the regional annexes. <p>This standard applies to systems with either condensing or non-condensing conditions in the exhaust gas.</p> <p>Different combustion air / flue duct circuit configurations are accommodated. See regional annexes for regional restrictions.</p> <p>This standard applies to both indoor and outdoor installations.</p> <p>This standard applies to systems with or without integrated batteries.</p> <p>This standard applies to Type Testing only.</p> <p>This standard specifies the requirements for construction, safety, installation, fitness for purpose, rational use of energy, marking, and performance measurement of these appliances.</p> <p>This Standard also provides regional and country specific requirements to facilitate the worldwide application of this IEC standard. These essential regional and country specific requirements are given in Annexes and will facilitate that the essential requirements for applications are given clearly.</p> <p>Note 1: Representation of experts from the various countries will be necessary to ensure good coverage.</p> <p>NOTE 2: The origin of this project is the European Standard EN 50465 that corresponds to the European Gas Appliance Directive. The goal of the forthcoming IEC standard is that the outcome will not only fit for the European law but to all national laws.</p>

WG	Work items	Scope
IEC/TC 105 WG 6	IEC/CD 62282-4-102: Fuel cell technologies – Part 4-102: Fuel cell systems for propulsion other than road vehicles and auxiliary power units (APU) – Performance test methods for electrically powered industrial trucks Edition 1.0	<p>1.1 This standard covers performance test methods of fuel cell power systems intended to be used for electrical powered industrial trucks.</p> <p>1.2 The scope of this standard is limited to electrical powered industrial trucks. Hybrid trucks that include an internal combustion engine are not included in the scope. The scope of this standard will be applicable to material handling equipment, e.g. forklifts.</p> <p>1.3 This standard applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrical powered industrial trucks.</p> <p>The following fuels are considered within the scope of this standard: – gaseous hydrogen, and – methanol</p> <p>1.4 This standard does not apply to reformer-equipped fuel cell power systems.</p> <p>1.5 This standard covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system. A fuel source container of the detachable type is not permitted.</p> <p>1.6 This standard applies to d.c. type fuel cell power systems, with a rated output voltage not exceeding 150 V d.c. for indoor and outdoor use.</p> <p>1.7 Fuel cell power systems intended for operation in potentially explosive atmospheres are excluded from the scope of this standard.</p> <p>1.8 This standard covers the fuel cell power system as defined in Figure 1-1 and 1-2.</p> <p>1.9 This standard does not cover the fuel storage systems using liquid hydrogen.</p> <p>1.10 Fuel cells used in forklift trucks are hybrids and so operate in several different modes. Similarly forklift trucks operate in different modes. The purpose of this document is to evaluate the fuel cell system in the various combinations of fuel cell modes and forklift truck modes. This document will break down these different modes and provide a framework for designing and evaluating a fuel cell system for use specifically in a forklift truck.</p> <p>1.11 All systems with integrated energy storage systems are covered by this standard. This includes systems, for example, batteries for internal recharges or recharged from an external source.</p>
IEC/TC 31 SC 31J	IEC 60079-10-1 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres Edition 2.0	To prepare and maintain international standards relating to the use of equipment including area classification, the selection and installation, inspection and maintenance, repair, overhaul and reclamation of equipment where there is a hazard due to the possible presence of explosive atmospheres of gases, vapours, mists or combustible dusts.

WG	Work items	Scope
IEC/TC 31	IEC 60079-29-1 Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases Edition 2.0	To prepare and maintain international standards relating to equipment for use where there is a hazard due to the possible presence of explosive atmospheres of gases, vapours, mists or combustible dusts

7.2 Annex 2

List of Published International RCS

Publication	Scope
ISO/TR 15916:2004 <i>Basic considerations for the safety of hydrogen systems</i>	<p>This Technical Report provides guidelines for the use of hydrogen in its gaseous and liquid forms. It identifies the basic safety concerns and risks, and describes the properties of hydrogen that are relevant to safety.</p> <p>Detailed safety requirements associated with specific hydrogen applications are treated in separate International Standards.</p>
ISO/TS 20100:2008 <i>Gaseous hydrogen — Fuelling stations</i>	<p>This Technical Specification specifies the characteristics of outdoor public and non-public fuelling stations that dispense gaseous hydrogen used as fuel onboard land vehicles of all types.</p> <p>Residential and home applications to fuel land vehicles are excluded from this technical specification.</p> <p>The fuelling station may comprise, as applicable, the following as shown in Figure 1:</p> <ul style="list-style-type: none"> • Delivery of hydrogen by pipeline, trucked in gaseous and/or liquid hydrogen; • On-site hydrogen generators using water electrolysis process or hydrogen generators using fuel processing technologies; • Liquid hydrogen storage, pumping and vaporizing systems; • Gaseous hydrogen compression and purification systems; <p>NOTE When the fuelling station comprises an on-site hydrogen generator, a compressor/purifier system is commonly integrated into it.</p> <ul style="list-style-type: none"> • Gaseous hydrogen buffer storage; • Gaseous hydrogen dispensers.
ISO 22734-1:2008 <i>Hydrogen generators using water electrolysis process — Part 1: Industrial and commercial applications</i>	<p>International Standard defines the construction, safety and performance requirements of packaged or factory matched hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyse water to produce hydrogen and oxygen gas.</p> <p>This International Standard is applicable to hydrogen generators that use the following types of ion transport medium:</p> <ul style="list-style-type: none"> • Group of aqueous bases; • Solid polymeric materials with acidic function group additions such as acid proton exchange membrane (PEM). <p>This part of ISO 22734 is applicable to hydrogen generators intended for indoor and outdoor commercial and industrial use (non-residential use). Hydrogen generators that can also be used to generate electricity such as reversible fuel cells are excluded from the scope of this International Standard.</p> <p>This International Standard is intended to be used for certification purposes.</p>

Publication	Scope
<p>ISO 22734-2:2011 Hydrogen generators using water electrolysis process — Part 2: Residential applications Edition 1</p>	<p>This standard defines the construction, safety and performance requirements of packaged hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyse water.</p> <p>This standard is applicable to hydrogen generators that use the following types of ion transport medium:</p> <ul style="list-style-type: none"> • group of aqueous bases; • solid polymeric materials with acidic function group additions such as acid proton exchange membrane (PEM). <p>This standard is applicable to hydrogen generators intended for indoor and outdoor residential use (non-commercial and non-industrial use) in sheltered areas such as car-ports, garages, utility rooms and similar areas of a residence. This standard includes cord-connected equipment for outdoor and garage use only.</p> <p>Hydrogen generators that can also be used to generate electricity such as reversible fuel cells are excluded from the scope of this standard.</p> <p>This standard does not include portable hydrogen generators.</p> <p>Hydrogen generators that also supply oxygen as a product are excluded from the scope of this standard.</p> <p>This standard is intended to be used for certification purposes.</p>
<p>ISO 26142:2010 Hydrogen detector apparatus- Stationary applications</p>	<p>Abstract: ISO 26142:2010 defines the performance requirements and test methods of hydrogen detection apparatus that is designed to measure and monitor hydrogen concentrations in stationary applications. The provisions in ISO 26142:2010 cover the hydrogen detection apparatus used to achieve the single and/or multilevel safety operations, such as nitrogen purging or ventilation and/or system shut-off corresponding to the hydrogen concentration. The requirements applicable to the overall safety system, as well as the installation requirements of such apparatus, are excluded. ISO 26142:2010 sets out only the requirements applicable to a product standard for hydrogen detection apparatus, such as precision, response time, stability, measuring range, selectivity and poisoning. ISO 26142:2010 is intended to be used for certification purposes.</p>
<p>IEC 62282-2:2012 Fuel cell technologies – Part 2: Fuel cell modules Edition 2.0</p>	<p>IEC 62282-2:2012 provides the minimum requirements for safety and performance of fuel cell modules; it applies to fuel cell modules with or without an enclosure which can be operated at significant pressurization levels or close to ambient pressure. Deals with conditions that can yield hazards to persons and cause damage outside the fuel cell modules.</p> <p>This edition includes the following significant technical changes with respect to the previous edition:</p> <ul style="list-style-type: none"> • inclusion of definitions for hazards and hazardous locations based on the IEC 60079 series; • modification of the general safety strategy and of the electrical components clause to reflect the needs for different application standards..
<p>IEC 62282-3-100 :2012 Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety Edition 1.0</p>	<p>Applies to stationary packaged, self-contained fuel cell power systems or fuel cell power systems comprised of factory matched packages of integrated systems which generate electricity through electrochemical reactions. Is a product safety standard suitable for conformity assessment.</p>

Publication	Scope
<p>IEC 62282-3-200:2011 Fuel cell technologies - Part 3-200: Stationary fuel cell power systems – Performance test methods Edition 1.0</p>	<p>This part of IEC 62282 covers operational and environmental aspects of the stationary fuel cell power systems performance. The test methods apply as follows:</p> <ul style="list-style-type: none"> – power output under specified operating and transient conditions; – electric and thermal efficiency under specified operating conditions; – environmental characteristics; for example, gas emissions, noise, etc. under specified operating and transient conditions. <p>This standard does not provide coverage for electromagnetic compatibility (EMC). This standard does not apply to small stationary fuel cell power systems with electric power output of less than 10 kW which will be dealt with in the future IEC 62282-3-201. Fuel cell power systems may have different subsystems depending upon types of fuel cell and applications, and they have different streams of material and energy into and out of them. However, a common system diagram and boundary has been defined for evaluation of the fuel cell power system (see Figure 1).</p> <p>The following conditions are considered in order to determine the test boundary of the fuel cell power system:</p> <ul style="list-style-type: none"> – all energy recovery systems are included within the test boundary; – all kinds of electric energy storage devices are considered outside the test boundary; – calculation of the heating value of the input fuel (such as natural gas, propane gas and pure hydrogen gas, etc.) is based on the conditions of the fuel at the boundary of the fuel cell power system.
<p>IEC 62282-3-300:2012 Fuel cell technologies - Part 3-300: Stationary fuel cell power systems – Installation Edition 1.0</p>	<p>Provides minimum safety requirements for the installation of indoor and outdoor stationary fuel cell power systems in compliance with IEC 62282-3-100; applies to the installation of systems intended for electrical connection to mains directly or with a transfer switch, or intended for a stand-alone power distribution system, or intended to provide AC or DC power.</p>
<p>IEC 62282-4-101:2014 Fuel cell technologies - Part 4-101: Fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU) – Safety of electrically powered industrial trucks Edition 1.0</p>	<p>1.1 This part of IEC 62282 covers safety requirements for fuel cell power systems intended to be used in electrically powered industrial trucks.</p> <p>1.2 This standard is limited to electrically powered industrial trucks and is applicable to material-handling equipment, e.g. forklifts.</p> <p>1.3 This standard applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.</p> <p>1.4 The following fuels are considered within the scope of this standard:</p> <ul style="list-style-type: none"> – gaseous hydrogen – methanol. <p>1.5 This standard covers the fuel cell power system as defined in 3.8 and Figure 1.</p> <p>1.6 This standard applies to d.c. type fuel cell power systems, with a rated output voltage not exceeding 150 V d.c. for indoor and outdoor use.</p> <p>1.7 This standard covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system.</p> <p>1.8 The following are not included in the scope of this standard:</p> <ul style="list-style-type: none"> – detachable type fuel source containers; – hybrid trucks that include an internal combustion engine; – reformer-equipped fuel cell power systems; – fuel cell power systems intended for operation in potentially explosive atmospheres; – fuel storage systems using liquid hydrogen.
<p>IEC 62282-5-1:2012 Fuel cell technologies - Part 5-1: Portable fuel cell power systems – Safety Edition 2.0</p>	<p>Covers construction, marking and test requirements for a.c. and d.c. type portable fuel cell systems. These fuel cell systems are movable and not fastened or otherwise secured to a specific location. The purpose of a portable fuel cell system is to produce useable power.</p>

Publication	Scope
<p>IEC 60079-10-1:2008 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres Edition 1.0</p>	<p>IEC 60079-10-1:2008 is concerned with the classification of areas where flammable gas or vapour or mist hazards may arise and may then be used as a basis to support the proper selection and installation of equipment for use in a hazardous area. It is intended to be applied where there may be an ignition hazard due to the presence of flammable gas or vapour, mixed with air under normal atmospheric conditions, but it does not apply to</p> <ul style="list-style-type: none"> a) mines susceptible to firedamp; b) the processing and manufacture of explosives; c) areas where a hazard may arise due to the presence of combustible dusts or fibres; d) catastrophic failures which are beyond the concept of abnormality; e) rooms used for medical purposes; f) domestic premises. <p>This first edition of IEC 60079-10-1 cancels and replaces the fourth edition of IEC 60079-10, published in 2002, and constitutes a technical revision. The significant technical changes with respect to the previous edition are:</p> <ul style="list-style-type: none"> - introduction of Annex D which deals with explosion hazard from flammable mists generated by the release under pressure of high flash point liquids; - introduction of Clause A.3 (release rate) which gives thermodynamic equations for release rate with a number of examples for estimating release rate of fluids and gases.
<p>IEC 60079-29-1 Edition 1.0 (2007-08-09) Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases</p>	<p>Specifies general requirements for construction, testing and performance, and describes the test methods that apply to portable, transportable and fixed apparatus for the detection and measurement of flammable gas or vapour concentrations with air. The apparatus, or parts thereof, are intended for use in potentially explosive atmospheres and in mines susceptible to firedamp. This first edition of IEC 60079-29-1 cancels and replaces the first edition of IEC 61779-1 to IEC 61779-5:1998 series and constitutes a technical revision with numerous changes with respect to the previous edition.</p>
<p>IEC 60079-29-2 Edition 1.0 (2007-08-16) Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen</p>	<p>This part of IEC 60079-29 gives guidance on, and recommended practice for, the selection, installation, safe use and maintenance of electrically operated group II apparatus intended for use in industrial and commercial safety applications for the detection and measurement of flammable gases complying with the requirements of IEC 60079-29-1. This first edition of IEC 60079-29-2 cancels and replaces the first edition of IEC 61779-6:1999 and constitutes a technical revision with many changes with respect to the previous edition.</p>