



BSI Standards Publication

Fuel cell technologies

Part 4-101: Fuel cell power systems for electrically
powered industrial trucks — Safety

National foreword

This British Standard is the UK implementation of EN 62282-4-101:2022. It is identical to IEC 62282-4-101:2022. It supersedes BS EN 62282-4-101:2014, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/105, Fuel cell technologies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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For the Great Britain market (England, Scotland and Wales), if UK Government has designated this publication for conformity with UKCA marking (or similar) legislation, it may contain an additional National Annex. Where such a National Annex exists, it shows the correlation between this publication and the relevant UK legislation. If there is no National Annex of this kind, the relevant Annex ZA or ZZ in the body of the European text will indicate the relationship to UK regulation applicable in Great Britain. References to EU legislation may need to be read in accordance with the UK designation and the applicable UK law. Further information on designated standards can be found at www.bsigroup.com/standardsandregulation.

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UK Government is responsible for legislation. For information on legislation and policies relating to that legislation, consult the relevant pages of www.gov.uk.

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Date

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Fuel cell technologies - Part 4-101: Fuel cell power systems for
electrically powered industrial trucks - Safety
(IEC 62282-4-101:2022)

Technologies des piles à combustible - Partie 4-101:
Systèmes à pile à combustible pour chariots de
manutention électriques - Sécurité
(IEC 62282-4-101:2022)

Brennstoffzellen-Technologien - Teil 4-101:
Brennstoffzellen-Energiesysteme für elektrisch betriebene
Flurförderfahrzeuge - Sicherheit
(IEC 62282-4-101:2022)

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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 105/912/FDIS, future edition 2 of IEC 62282-4-101, prepared by IEC/TC 105 "Fuel cell technologies" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62282-4-101:2022.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2023-06-15
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2025-09-15

This document supersedes EN 62282-4-101:2014 and all of its amendments and corrigenda (if any).

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The text of the International Standard IEC 62282-4-101:2022 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60034 (series)	NOTE Harmonized as EN 60034 (series)
IEC 60034-11	NOTE Harmonized as EN 60034-11
IEC 60112	NOTE Harmonized as EN IEC 60112
IEC 60243 (series)	NOTE Harmonized as EN 60243 (series)
IEC 60695-11-5	NOTE Harmonized as EN 60695-11-5
IEC 62282-3-100	NOTE Harmonized as EN IEC 62282-3-100
IEC 62282-5-100	NOTE Harmonized as EN IEC 62282-5-100
ISO/IEC 80079-20-1	NOTE Harmonized as EN ISO/IEC 80079-20-1
ISO 16017-1	NOTE Harmonized as EN ISO 16017-1

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-485	-	International Electrotechnical Vocabulary (IEV) - Part 485: Fuel cell technologies	-	-
IEC 60079-0	-	Explosive atmospheres - Part 0: Equipment - General requirements	EN IEC 60079-0	-
IEC 60079-10-1	-	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres	EN IEC 60079-10-1	-
IEC 60079-29-1	-	Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases	EN 60079-29-1	-
IEC 60079-29-4	-	Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases	EN 60079-29-4	-
IEC 60204-1	-	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	EN 60204-1	-
IEC 60227-3	-	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 3: Non-sheathed cables for fixed wiring	-	-
IEC 60227-5	-	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 5: Flexible cables (cords)	-	-
IEC 60335-2-41	-	Household and similar electrical appliances - Safety - Part 2-41: Particular requirements for pumps	EN IEC 60335-2-41	-
IEC 60335-2-80	-	Household and similar electrical appliances - Safety - Part 2-80: Particular requirements for fans	EN 60335-2-80	-

EN IEC 62282-4-101:2022 (E)

IEC 60364-4-41 (mod)	2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	HD 60364-4-41	2017
AMD1	2017		/A11	2017
-	-		/A12	2019
IEC 60529	-	Degrees of protection provided by enclosures (IP Code)	-	-
IEC 60584-1	-	Thermocouples - Part 1: EMF specifications and tolerances	EN 60584-1	-
IEC 60664-1	-	Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests	EN IEC 60664-1	-
IEC 60695	series	Fire hazard testing	EN IEC 60695	series
IEC 60695-1-30	-	Fire hazard testing - Part 1-30: Guidance for assessing the fire hazard of electrotechnical products - Preselection testing process - General guidelines	EN 60695-1-30	-
IEC 60695-10-2	-	Fire hazard testing - Part 10-2: Abnormal heat - Ball pressure test method	EN 60695-10-2	-
IEC 60695-11-4	-	Fire hazard testing - Part 11-4: Test flames - 50 W flame - Apparatus and confirmational test method	EN 60695-11-4	-
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC 60730-1 (mod)	2013	Automatic electrical controls - Part 1: General requirements	EN 60730-1	2016
AMD1	2015		/A1	2019
AMD2	2020		/A2	2022
IEC 60812	-	Failure modes and effects analysis (FMEA and FMECA)	EN IEC 60812	-
IEC 60947-3	-	Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units	EN IEC 60947-3	-
IEC 60947-5-1	-	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices	EN 60947-5-1	-
IEC 60950-1	2005	Information technology equipment - Safety - Part 1: General requirements		-
AMD1	2009		-	-
AMD2	2013		-	-
IEC 61025	-	Fault tree analysis (FTA)	EN 61025	-
IEC 61204-7	-	Low-voltage switch mode power supplies - Part 7: Safety requirements	EN IEC 61204-7	-

IEC/TS 61430	-	Secondary cells and batteries - Test methods for checking the performance of devices designed for reducing explosion hazards - Lead-acid starter batteries	-	-
IEC 61508	series	Functional safety of electrical/electronic/programmable electronic safety-related systems	EN 61508	series
IEC 61558-1	-	Safety of transformers, reactors, power supply units and combinations thereof - Part 1: General requirements and tests	EN IEC 61558-1	-
IEC 62477-1	-	Safety requirements for power electronic converter systems and equipment - Part 1: General	EN 62477-1	-
IEC 62133-1	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 1: Nickel systems	EN 62133-1	-
IEC 62282-2-100	-	Fuel cell technologies - Part 2-100: Fuel cell modules - Safety	EN IEC 62282-2-100	-
IEC 62391-1	-	Fixed electric double-layer capacitors for use in electric and electronic equipment - Part 1: Generic specification	EN 62391-1	-
IEC 62391-2	-	Fixed electric double-layer capacitors for use in electronic equipment - Part 2: Sectional specification - Electric double layer capacitors for power application	EN 62391-2	-
IEC 62619	-	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	EN IEC 62619	-
IEC/ISO 31010	-	Risk management - Risk assessment techniques	EN IEC 31010	-
ISO 179	series	Plastics - Determination of Charpy impact properties	EN ISO 179	series
ISO 180	-	Plastics - Determination of Izod impact strength	EN ISO 180	-
ISO 877	series	Plastics - Methods of exposure to solar radiation	EN ISO 877	series
ISO 1419	-	Rubber- or plastics-coated fabrics - Accelerated-ageing tests	-	-
ISO 1421	-	Rubber- or plastics-coated fabrics – Determination of tensile strength and elongation at break	EN ISO 1421	-
ISO 1798	-	Flexible cellular polymeric materials - Determination of tensile strength and elongation at break	EN ISO 1798	-
ISO 2440	-	Flexible and rigid cellular polymeric materials - Accelerated ageing tests	EN ISO 2440	-

ISO 2626	-	Copper - Hydrogen embrittlement test	EN ISO 2626	-
ISO 3691-1	-	Industrial trucks - Safety requirements and verification - Part 1: Self-propelled industrial trucks, other than driverless trucks, variable-reach trucks and burden-carrier trucks	EN ISO 3691-1	-
ISO/TS 3691-7	-	Industrial trucks - Safety requirements and verification - Part 7: Regional requirements for countries within the European Community		-
ISO/TS 3691-8	-	Industrial trucks - Safety requirements and verification - Part 8: Regional requirements for countries outside the European Community		-
ISO 3864-1	-	Graphical symbols - Safety colours and safety signs - Part 1: Design principles for safety signs and safety markings		-
ISO 4038	-	Road vehicles - Hydraulic braking systems - Simple flare pipes, tapped holes, male fittings and hose end fittings		-
ISO 4080	-	Rubber and plastics hoses and hose assemblies - Determination of permeability to gas	EN ISO 4080	-
ISO 4675	-	Rubber- or plastics-coated fabrics - Low-temperature bend test		-
ISO 5053-1	-	Industrial trucks - Vocabulary - Part 1: Types of industrial trucks		-
ISO 7010	-	Graphical symbols - Safety colours and safety signs - Registered safety signs	EN ISO 7010	-
ISO 10380	-	Pipework - Corrugated metal hoses and hose assemblies	EN ISO 10380	-
ISO 10442	-	Petroleum, chemical and gas service industries - Packaged, integrally geared centrifugal air compressors	EN ISO 10442	-
ISO 10806	-	Pipework - Fittings for corrugated metal hoses	EN ISO 10806	-
ISO 11114-4	-	Transportable gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 4: Test methods for selecting steels resistant to hydrogen embrittlement	EN ISO 11114-4	-
ISO 12100	-	Safety of machinery - General principles for design - Risk assessment and risk reduction	EN ISO 12100	-
ISO 13226	-	Rubber - Standard reference elastomers (SREs) for characterizing the effect of liquids on vulcanized rubbers		-
ISO 13849-1	-	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	EN ISO 13849-1	-

ISO 13849-2	-	Safety of machinery - Safety-related parts of control systems - Part 2: Validation	EN ISO 13849-2	-
ISO 14113	-	Gas welding equipment – Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)	EN ISO 14113	-
ISO 15649	-	Petroleum and natural gas industries - Piping	-	-
ISO/TR 15916	-	Basic considerations for the safety of hydrogen systems	-	-
ISO 16010	-	Elastomeric seals - Material requirements for seals used in pipes and fittings carrying gaseous fuels and hydrocarbon fluids	-	-
ISO 16111	2018	Transportable gas storage devices - Hydrogen absorbed in reversible metal hydride	-	-
ISO 17268	-	Gaseous hydrogen land vehicle refuelling connection devices	EN ISO 17268	-
ISO 19881	-	Gaseous hydrogen - Land vehicle fuel containers	-	-
ISO 19882	-	Gaseous hydrogen - Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers	-	-
ISO 20898	-	Industrial trucks - Electrical requirements	-	-
ISO 21927-3	-	Smoke and heat control systems - Part 3: Specification for powered smoke and heat exhaust ventilators	-	-
ISO 23551-1	-	Safety and control devices for gas burners - and gas-burning appliances - Particular requirements - Part 1: Automatic and semi-automatic valves	-	-
UN GTR No. 13	-	Global Technical Regulation concerning the hydrogen and fuel cell vehicles	-	-
UN Regulation No.-134	-	Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles (HFCV)	-	-

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Fuel cell technologies –

**Part 4-101: Fuel cell power systems for electrically powered industrial trucks –
Safety**

Technologies des piles à combustible –

**Partie 4-101: Systèmes à pile à combustible pour chariots de manutention
électriques – Sécurité**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FUEL CELL TECHNOLOGIES –

**Part 4-101: Fuel cell power systems for
electrically powered industrial trucks – Safety**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62282-4-101 has been prepared by IEC technical committee 105: Fuel cell technologies.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

- a) revision of the title of this document;
- b) revision of reference standards;
- c) addition of new subclauses (4.3, 4.14.5, 4.15.3, 4.15.4, 4.16, 5.6, and 5.23);
- d) previous 4.15 was revised as “4.16 Risk assessment and risk reduction”;
- e) revision of 4.6 3), access to the manual shutoff valve;
- f) revision of requirements for battery terminals that are threaded (4.14.10.1);



- g) revision of requirements for double layer capacitors (4.14.10.2);
- h) revision of external leakage test (5.5) and ultimate strength test (5.7);
- i) revision of temperature limits on capacitors depending on the temperature rating of the material (Table 3);
- j) revision of markings that are not relevant (Clause 7);
- k) added “Significant hazards, hazardous situations and events dealt with in this document” as a new informative annex (Annex B).

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

Draft	Report on voting
105/912/FDIS	105/922/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The IEC 62282-4 series deals with categories such as safety, performance and interchangeability of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU). Among the categories mentioned above, this document, IEC 62282-4-101, focuses on safety of electrically powered industrial trucks with fuel cell power systems because such applications are urgently demanded in the world. Future documents in this part of IEC 62282-4 will deal with other applications related to onboard vehicles other than road vehicles and auxiliary power units (APU).

FUEL CELL TECHNOLOGIES –

Part 4-101: Fuel cell power systems for electrically powered industrial trucks – Safety

1 Scope

This document deals with safety of fuel cell power systems for propulsion other than road vehicles and auxiliary power units (APU).

This part of IEC 62282 covers safety requirements for fuel cell power systems intended to be used in electrically powered industrial trucks as defined in ISO 5053-1, except for:

- rough-terrain trucks;
- non-stacking low-lift straddle carriers;
- stacking high-lift straddle carriers;
- rough-terrain variable-reach trucks;
- slewing rough-terrain variable-reach trucks;
- variable-reach container handlers;
- pedestrian propelled trucks.

This document applies to gaseous hydrogen-fuelled fuel cell power systems and direct methanol fuel cell power systems for electrically powered industrial trucks.

The following fuels are considered within the scope of this document:

- gaseous hydrogen;
- methanol.

This document covers the fuel cell power system as defined in 3.8 and Figure 1.

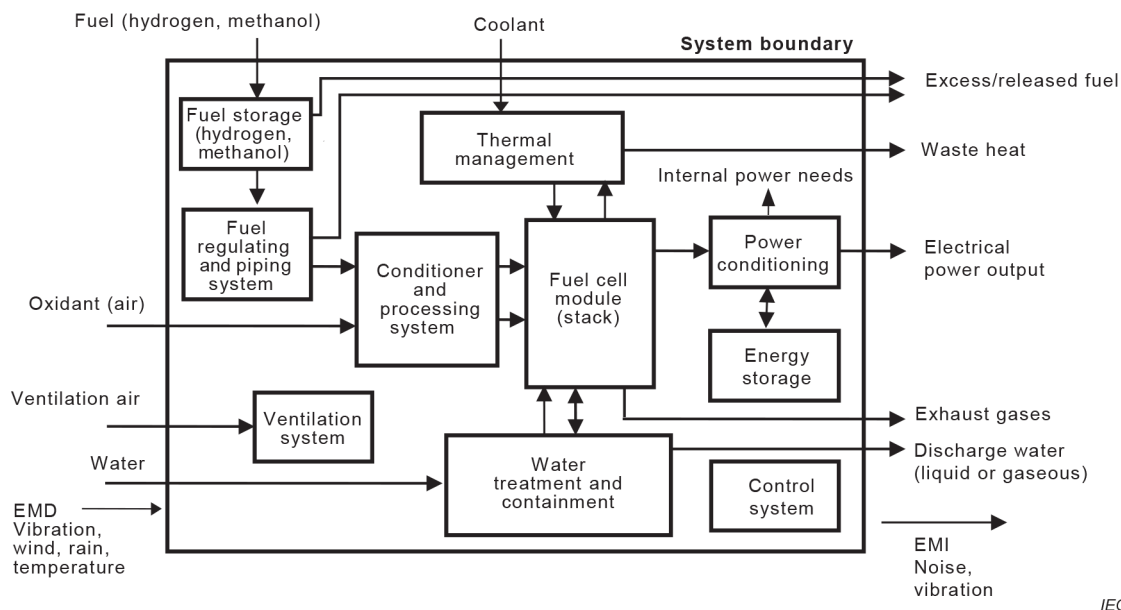
This document applies to DC type fuel cell power systems, with a rated output voltage not exceeding 150 V DC for indoor and outdoor use.

This document covers fuel cell power systems whose fuel source container is permanently attached to either the industrial truck or the fuel cell power system.

In accordance with IEC Guide 116, significant hazards, hazardous situations and events dealt with in this document are shown in Annex B.

The following are not included in the scope of this document:

- 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.



Key

EMD electromagnetic disturbance

EMI electromagnetic interference

NOTE A fuel cell power system can contain all or some of the above components.

Figure 1 – Fuel cell power systems for industrial trucks

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-485, *International Electrotechnical Vocabulary (IEV) – Part 485: Fuel cell technologies*

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60079-29-4, *Explosive atmospheres – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60227-3, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring*

IEC 60227-5, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 5: Flexible cables (cords)*

IEC 60335-2-41, *Household and similar electrical appliances – Safety – Part 2-41: Particular requirements for pumps*

IEC 60335-2-80, *Household and similar electrical appliances – Safety – Part 2-80: Particular requirements for fans*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-41:2005/AMD1:2017

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695 (all parts), *Fire hazard testing*

IEC 60695-1-30, *Fire hazard testing – Part 1-30: Guidance for assessing the fire hazard of electrotechnical products – Preselection testing process – General guidelines*

IEC 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

IEC 60695-11-4, *Fire hazard testing – Part 11-4: Test flames – 50 W flame – Apparatus and confirmational test method*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60730-1:2013, *Automatic electrical controls – Part 1: General requirements*

IEC 60730-1:2013/AMD1:2015

IEC 60730-1:2013/AMD2:2020

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 60950-1:2005/AMD1:2009

IEC 60950-1:2005/AMD2:2013

IEC 61025, *Fault tree analysis (FTA)*

IEC 61204-7, *Low-voltage switch mode power supplies – Part 7: Safety requirements*

IEC TS 61430, *Secondary cells and batteries – Test methods for checking the performance of devices designed for reducing explosion hazards – Lead-acid starter batteries*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61558-1, *Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*

IEC 62477-1, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62133-1, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 1: Nickel systems*

IEC 62282-2-100, *Fuel cell technologies – Part 2-100: Fuel cell modules – Safety*

IEC 62391-1, *Fixed electric double-layer capacitors for use in electric and electronic equipment – Part 1: Generic specification*

IEC 62391-2, *Fixed electric double-layer capacitors for use in electronic equipment – Part 2: Sectional specification – Electric double layer capacitors for power application*

IEC 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC/ISO 31010, *Risk management – Risk assessment techniques*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

ISO 180, *Plastics – Determination of Izod impact strength*

ISO 877 (all parts), *Plastics – Methods of exposure to solar radiation*

ISO 1419, *Rubber- or plastics-coated fabrics – Accelerated-ageing tests*

ISO 1421, *Rubber- or plastics-coated fabrics – Determination of tensile strength and elongation at break*

ISO 1798, *Flexible cellular polymeric materials – Determination of tensile strength and elongation at break*

ISO 2440, *Flexible and rigid cellular polymeric materials – Accelerated ageing tests*

ISO 2626, *Copper – Hydrogen embrittlement test*

ISO 3691-1, *Industrial trucks – Safety requirements and verification – Part 1: Self-propelled industrial trucks, other than driverless trucks, variable-reach trucks and burden-carrier trucks*

ISO/TS 3691-7, *Industrial trucks – Safety requirements and verification – Part 7: Regional requirements for countries within the European Community*

ISO/TS 3691-8, *Industrial trucks – Safety requirements and verification – Part 8: Regional requirements for countries outside the European Community*

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 4038, *Road vehicles – Hydraulic braking systems – Simple flare pipes, tapped holes, male fittings and hose end fittings*

ISO 4080, *Rubber and plastics hoses and hose assemblies – Determination of permeability to gas*

ISO 4675, *Rubber- or plastics-coated fabrics – Low-temperature bend test*

ISO 5053-1, *Industrial trucks – Vocabulary – Part 1: Types of industrial trucks*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 10380, *Pipework – Corrugated metal hoses and hose assemblies*

ISO 10442, *Petroleum, chemical and gas service industries – Packaged, integrally geared centrifugal air compressors*

ISO 10806, *Pipework – Fittings for corrugated metal hoses*

ISO 11114-4, *Transportable gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 4: Test methods for selecting metallic materials resistant to hydrogen embrittlement*

ISO 12100, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13226, *Rubber – Standard reference elastomers (SREs) for characterizing the effect of liquids on vulcanized rubbers*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 14113, *Gas welding equipment – Rubber and plastics hose and hose assemblies for use with industrial gases up to 450 bar (45 MPa)*

ISO 15649, *Petroleum and natural gas industries – Piping*

ISO/TR 15916, *Basic considerations for the safety of hydrogen systems*

ISO 16010, *Elastomeric seals – Material requirements for seals used in pipes and fittings carrying gaseous fuels and hydrocarbon fluids*

ISO 16111:2018, *Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride*

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices*

ISO 19881, *Gaseous hydrogen – Land vehicle fuel containers*

ISO 19882, *Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers*

ISO 20898, *Industrial trucks – Electrical requirements*

ISO 21927-3, *Smoke and heat control systems – Part 3: Specifications for powered smoke and heat exhaust ventilators*

ISO 23551-1, *Safety and control devices for gas burners and gas-burning appliances – Part 1: Automatic and semi-automatic valves*

UN GTR No. 13, *Global Technical Regulation concerning the hydrogen and fuel cell vehicles*

UN Regulation No. 134, *Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles (HFCV)*

3 Terms and definitions

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

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

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

3.1

abnormal operation

operation of the fuel cell power system with any one mechanical, electrical or control component malfunction or failure, in any failure mode regarded as reasonably probable in the failure mode and effects analysis (FMEA) but excluding accidental rupture or breakdown of the containers of flammable liquids, and/or gases

3.2

equipotential bonding

permanent joining of conductive parts to form a positive electrically conductive path that provides electrical continuity between non-current carrying conductive parts and is capable of conducting any fault current that can occur

Note 1 to entry: This applies to bonding within the fuel cell system and between the fuel cell system and truck and does not refer to the means to earth the truck itself, such as with an earthing strap or with tires.

3.3

check-valve

fluid control device that allows fluids to flow in only one direction

3.4

limited power circuit

circuit involving a potential greater than 42,4 V peak (30 V RMS) or 60 V DC and whose power after 60 s of operation complies with the values outlined in Table 2B and Table 2C of IEC 60950-1:2005 and IEC 60950-1:2005/AMD2:2013

Note 1 to entry: A circuit that is low voltage under both normal and single fault conditions is referred to in IEC 60950-1 as a safety extra low voltage (SELV).

3.5

low-voltage circuit

circuit involving a peak open-circuit potential of not more than 42,4 V (30 V RMS) or 60 V DC supplied by a battery, a fuel cell, a transformer having a rated power output rating of less than 100 VA and a maximum secondary output of 30 V AC or by a combination of a transformer and a fixed impedance that, as a system, complies with IEC 61558-1

Note 1 to entry: A circuit derived by connecting a resistance in series with a voltage supply circuit as a means of limiting the voltage and current is not considered to be a low-voltage circuit.

3.6

dilution boundary

extent of a flammable area or zone created by a limited release of flammable gas, internal to the fuel cell power system or truck in which it is mounted, and controlled by mechanical ventilation or other effective means

Note 1 to entry: This is outlined in IEC 60079-10-1.

3.7

electrostatic discharge

ESD

transfer of electric charge between bodies of different electrostatic potentials in proximity or through direct contact

[SOURCE: IEC 60050-561:2014, 561-03-06]

3.8

fuel cell power system

generator system that uses one or more fuel cell modules to generate electric power and heat

Note 1 to entry: See Figure 1 for a block diagram of a fuel cell power system. The fuel cell power system for use with industrial trucks will be in one of the forms as outlined in 3.9 and 3.10.

[SOURCE: IEC 60050-485:2020, 485-09-01, modified – addition of the Note to entry.]

3.9

self-contained system

complete system incorporated into its own housing that is intended to replace or combine with a battery system to power an industrial truck

Note 1 to entry: Display and control functions can be located outside the system's housing in proximity to the operator's compartment. However, if counterweight is required outside the system's housing or direct communication is required between the system and the truck controller, then it will be considered an integrated system (see 3.10).

3.10

integrated fuel cell power system

complete system of fuel cell components and parts that are incorporated into the industrial truck with the various parts of the system potentially distributed throughout the truck

3.11

hazardous zone

any work area or space where combustible dust, ignitable fibres, or flammable, volatile liquids, gases, or mixtures are or can be present in the air in quantities sufficient to produce explosive or ignitable mixtures as defined by IEC 60079-10-1

3.12

integral

something that is either contained within the fuel cell power system or is external to it, but is a part of the fuel cell power system

3.13

lower flammability limit

LFL

minimum concentration of fuel in a fuel-air mixture where a combustion can be ignited by an ignition source

Note 1 to entry: A fuel-air mixture is flammable when combustion can be started by an ignition source. The main component concerns the proportions or composition of the fuel-air mixture. A mixture that has less than a critical amount of fuel, known as the lower flammability limit (LFL) or more than a critical amount of fuel, known as the rich or upper flammability limit (UFL), will not be flammable.

3.14**maximum allowable working pressure****MAWP**

maximum gauge pressure at which a fuel cell or fuel cell power system can be operated

Note 1 to entry: See Annex A for a comparison table of pressure terms.

Note 2 to entry: The maximum allowable working pressure is expressed in Pa.

Note 3 to entry: The maximum allowable working pressure is the pressure used in determining the setting of pressure limiting/relieving devices installed to protect a component or system from accidental over-pressuring.

[SOURCE: IEC 60050-485:2020, 485-17-03, modified – addition of new Note 1 to entry.]

3.15**maximum operating pressure****MOP**

highest gauge pressure of a component or the system that is expected during normal operation

Note 1 to entry: See Annex A for a comparison table of pressure terms.

3.16**normal release**

limited localized volumes of hydrogen concentrations released during normal operation that can include fuel cell purge

3.17**normal operation**

all operating and non-operating modes encountered during product use that are not the result of a malfunction or failure

3.18**pressure relief device****PRD**

pressure and/or temperature activated device used to prevent the pressure from rising above a predetermined maximum and thereby prevent failure of a pressurized part or system

3.19**thermally activated pressure relief device****TPRD**

pressure relief device (3.18) activated by temperature

3.20**risk assessment**

overall process comprising a risk analysis and a risk evaluation

3.21**risk analysis**

systemic use of available information to identify hazards and to estimate the risk

3.22**risk evaluation**

procedure based on the risk analysis to determine whether a tolerable risk has been achieved

3.23**safety control**

automatic controls and interlocks including relays, switches, sensors and other auxiliary equipment used in conjunction therewith to form a safety control system, which is intended to prevent unsafe operation of the controlled equipment

3.24**safety critical component**

component, device, circuit, software or similar part whose failure would affect the safety of the fuel cell power system as determined in 4.16

3.25**service pressure****nominal working pressure**

pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C and with full gas content

Note 1 to entry: This term only relates to the hydrogen pressure vessel.

Note 2 to entry: See Annex A for a comparison table of pressure terms.

3.26**zone system of classification**

means for classifying areas within the fuel cell power system using the methods outlined in IEC 60079-10-1

4 Construction requirements for safety**4.1 General**

Any component of a product covered by this document shall comply with the requirements for that component. Normative references for standards covering components used in the products covered by this document are given in Clause 2.

A component is not required to comply with a specific requirement of the normatively referenced standards that:

- involves a feature or characteristic not required in the application of the component in the product covered by this document,
- is superseded by a requirement in this document, or
- is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

Any component shall be used in accordance with its rating established for the intended conditions of use.

Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall additionally comply with the requirements of the applicable standard that covers devices that provide those functions.

4.2 Hydrogen and other fluid containing parts

4.2.1 General

Pressure or fluid containing parts shall be resistant to the action of the fluid.

Metallic parts containing hydrogen gas shall be resistant to hydrogen embrittlement as outlined in ISO/TR 15916. If employing a material other than as outlined in ISO/TR 15916, an evaluation for susceptibility to hydrogen embrittlement will need to be conducted in accordance with ISO 11114-4 or ISO 2626.

Where atmospheric corrosion of a part containing fluid interferes with its intended function, or permits external leakage of a fluid creating a hazardous condition, the part shall be made of corrosion-resistant material or is to be provided with a corrosion-resistant protective coating.

Any elastomeric parts, relied upon for safety such as a seal for fluids other than hydrogen, which could create a hazard when leaked (for example, a gasket between electrical and wetted parts), shall be suitable for the application as determined by ISO 1419, ISO 1421, ISO 13226, ISO 16010 and ISO 4675, as applicable.

Any elastomeric parts employed as a seal for hydrogen shall be suitable for use with hydrogen. The elastomeric materials outlined in ISO/TR 15916 shall be considered for reference and guidance. The material shall be evaluated for tensile strength and elongation as-received and after oven-ageing (based on service temperatures) in accordance with 5.20.

4.2.2 Piping, hoses, tubing and fittings

- 1) Where conveying gases at gauge pressures exceeding 103,4 kPa, liquids at pressures exceeding 1 103 kPa, or temperatures exceeding 120 °C, piping and associated component parts shall be designed, fabricated and tested to conform to all applicable specifications of ISO 15649.
- 2) Piping utilized at levels below the pressures and/or temperatures noted in 1) and nonmetallic piping shall be evaluated to the requirements of this document with consideration given to materials and fluids contained and service conditions, including pressures and temperatures. Non-metallic piping containing gaseous hydrogen or methanol fuel shall be designed, fabricated and tested to the additional requirements in 6).
- 3) Non-metallic hoses used for gaseous hydrogen or methanol fuels located outside the fuel cell power system and subject to physical stress shall meet the hydrostatic testing, adhesion (rubber only), flexibility, low-temperature flexibility, ozone resistance (for hoses with an outer protective cover of rubber), UV resistance (for hoses with plastic cover), permeability to gas, electrical conductivity, and end fitting integrity tests of ISO 14113. Materials shall be suitable for service with hydrogen fuel, or the fluid contained (i.e. methanol), in accordance with 4.2.1. Flexible hoses longer than 1,5 m shall have a stainless-steel wire braid reinforcement.
- 4) Flexible metal connectors and associated fittings, when used for conveying gaseous hydrogen, shall comply with ISO 10806 and ISO 10380, as required.
- 5) A hydrogen fuel line shall be supported to minimize chafing and to maintain at least a 51 mm clearance from exhaust- and electrical-system parts.
 - a) Electrical equipment and sensors in limited power circuits that do not have enough electrical energy to damage a fuel line are not required to comply with this requirement.
 - b) If it can be demonstrated that the fuel lines and wiring are sufficiently supported to prevent the clearance from being reduced to less than 12,7 mm, the clearance between fuel lines and electrical-system parts can be reduced.

- 6) Non-metallic hydrogen and methanol fuel lines shall:
 - be protected within ventilated enclosures where they will be subject to a minimum of mechanical or physical stresses;
 - be conductive to avoid static discharge. Compliance is determined by the continuity test of 5.10 2) for metal fuel lines, and of 5.10 3), for nonmetallic fuel lines;
 - employ materials that have been evaluated and found suitable for the fluids they contain with consideration given to temperatures they are exposed to during service. Compliance shall be determined by 5.20 and 5.21, as applicable; and
 - comply with the ESD requirements for ISO 4038 when connected between the fuel system and the stack.
- 7) Pipe, tubing, fittings, and other piping components shall be capable of withstanding a minimum hydrostatic test of 1,5 times the rated service pressure without structural failure. High-pressure pipe, tubing, fittings, and other piping components shall have a safety margin equivalent to the storage cylinder in use. See 4.2.3.

4.2.3 Hydrogen pressure vessels

- 1) Pressure vessels shall be specifically designed for the service conditions of the industrial truck application that include the maximum number of fill cycles expected, the ranges of pressures and temperatures expected during operation and filling, the effect of hydrogen on fatigue life and the frequency of inspection.
- 2) With reference to 1), a pressure vessel shall be designed, manufactured, and tested with the following conditions and limitations:
 - a) container Category C defined in ISO 19881 shall apply;
 - b) for Type 1 vessels, the vessel shall be designed and tested in accordance with ISO 19881;
 - c) the term "working pressure" of the vessel as defined in ISO 19881 is identical to "service pressure" in this document;
 - d) for Type 3 and Type 4 vessels, the vessel shall be designed and tested in accordance with ISO 19881, UN GTR No.13 and UN Regulation No. 134;
 - e) the vessel shall be designed for the expected life of the fuel cell power system and not fewer than 11 250 full fill cycles.

NOTE "11 250 full fill cycles", for example, 3 refills/day, 365 days/years, 10 years = 10 950 cycles.

- 3) A pressure vessel and fill fitting shall be placed within the plan view outline of the industrial truck or placed in an enclosure as defined in 4.13 and located to minimize the possibility of damage to the vessel or hydrogen-related fittings.
- 4) An excess-flow and check-valve, if present, shall be directly connected to the pressure vessel or mounted in line with the pressure vessel, where there is no shut-off device in between the pressure vessel and the check valve, so as to minimize the negative effects of shock, vibration and accidental damage.
- 5) The refuelling line shall be fitted with a redundant check valve for the check valve in the receptacle specified in ISO 17268.
- 6) Pressure vessels shall have a provision for being de-fuelled (de-pressurized) and purged of hydrogen using an inert gas as outlined in the operating instructions or the maintenance manual, as applicable, provided with the fuel cell power system.
- 7) A manual valve to isolate the fuel supply shall be located near the pressure vessel so that the fuel supply to the fuel power system can be shut off for maintenance or long-term storage.
- 8) The hydrogen pressure vessel shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the pressure vessel does not become dislodged while in use and is not removable for refuelling.

4.2.4 Metal hydride container

Fuel storage systems using hydrogen stored in metal hydrides shall comply with Clause 4, Clause 5, and Clause 6 of ISO 16111:2018.

4.2.5 Methanol fuel tank

- 1) Methanol fuel vessels shall be constructed of suitable materials in accordance with 4.2.1 and 4.2.2 and shall meet the requirements as noted below. Such vessels, and their related joints and fittings, shall be designed and constructed with adequate strength for functionality and leakage resistance to prevent unintended releases.
- 2) Methanol fuel vessels shall be specifically designed for the service conditions of the industrial truck application that includes the ranges of pressures and temperatures expected during operation and filling, the effect of methanol on fatigue life of the tank, and the frequency of inspection.
- 3) A manual valve to isolate the fuel supply shall be located near the fuel tank so that the fuel supply to the fuel cell power system can be shut off for maintenance or long term storage.
- 4) A methanol fuel vessel and fill fitting shall be placed within the truck envelope or placed in an enclosure as defined in 4.13, and located to minimize the possibility of damage to the vessel or fittings.
- 5) The methanol fuel tank shall be permanently mounted to the fuel cell power system module or to the industrial truck to ensure the tank does not become dislodged while in use and is not removable for refuelling.

4.3 Refueling

The refueling interface shall correspond to the container pressure rating (see 4.2.3 2)c)) and shall be in accordance with ISO 17268.

4.4 Over-pressure and thermal protection

- 1) The hydrogen pressure vessel shall be protected from the effects of fire by a nonreclosing thermally activated pressure relief device (TPRD) that is designed, manufactured and tested in accordance with ISO 19882.
- 2) Components and piping located downstream of a pressure reducing valve that are rated to a pressure that is lower than the maximum inlet pressure of the pressure reducing valve shall be protected from over-pressure in the event of a failure of the pressure reducing valve by way of a pressure relief device.
- 3) Pressure relief devices shall be suitable for their application, including materials in contact with hydrogen and pressure and flow ratings.
- 4) Pressure relief devices operating at over 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 110 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Pressure relief devices operating at or below 1 000 kPa shall be sized and designed to limit the pressure during a fault to less than 125 % of the maximum allowable working pressure. Re-closure shall occur at no less than 90 % of the set point. Fuel cell stack shall be protected in accordance with IEC 62282-2-100.
- 5) When provided, pressure relief discharge piping shall be sized to ensure compliance with 4.4 4).
- 6) A pressure relief device shall have its discharge located so that operation of the named device does not result in a hazardous situation such as:
 - a) hydrogen gas in excess of 25 % of the lower flammability limit (LFL) escaping to an unclassified or pressure-confined area within the fuel cell power system. The discharge of the pressure relief device can be located within the fuel cell power system by using an adequate ventilation or implementing an adequate safety-controlled system composed of a hydrogen sensor and a hydrogen shut-off valve plugging the leak in case of detection;
 - b) deposition of moisture on live parts that could create a risk of electric shock;

- c) possible access of foreign objects, moisture or debris to enter the venting system not protected by caps, covers or other means;
 - d) chance for the venting system to become unsecured or removed such that it would affect the intended flow path, or
 - e) the pressure release being directed towards or impinged towards the normal operator position.
- 7) A pressure relief device vent shall be secured at intervals in such a manner as to minimize the possibility of damage, corrosion, or breakage of either the vent line or the pressure relief device due to expansion, contraction, vibration, strains, or wear and to preclude any loosening while in operation.
 - 8) The vent system including the outlet connection of the relief device and associated vent lines shall be designed to withstand the maximum pressure developed during full flow operation of the relief device without becoming detached from its securement. If provided, the vent cap shall be secured for the safety.
 - 9) Pressure relief devices, as shown in the examples in Figure 2, Figure 3, and Figure 4, shall be in accordance with ISO 15649.

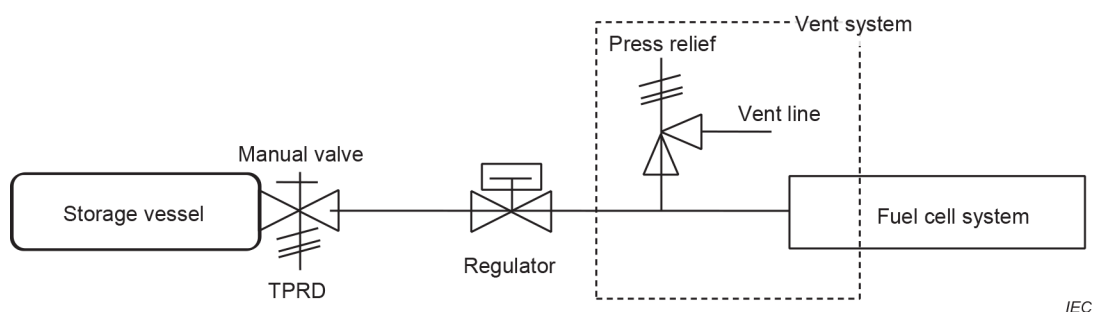


Figure 2 – Example of a diagram with vent system covering components downstream of the regulator

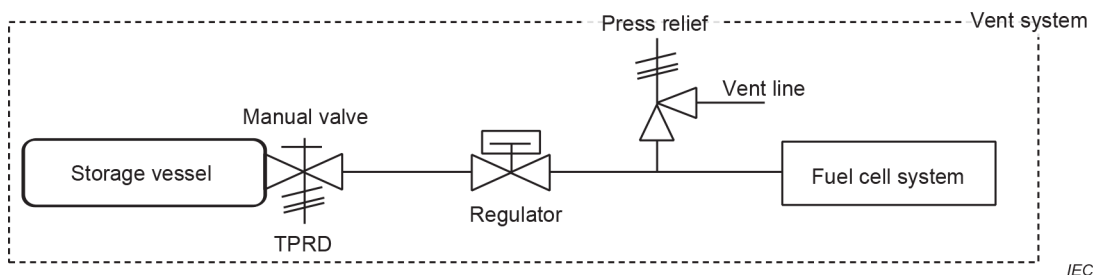


Figure 3 – Example of a diagram with vent system covering all components

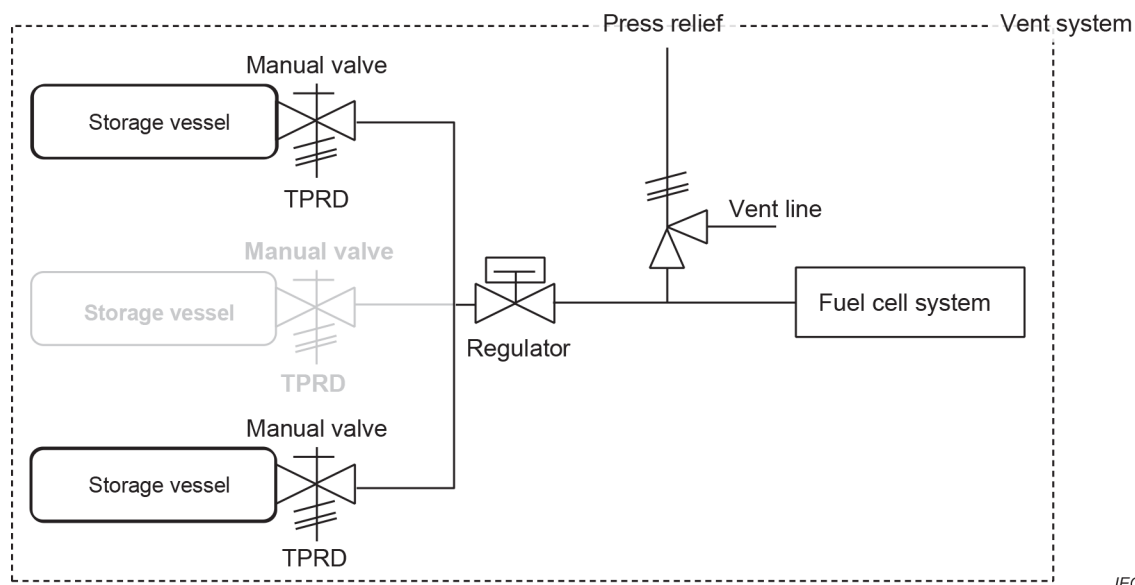


Figure 4 – Example of a diagram with vent system covering all components in a multiple storage vessel system

4.5 Regulators

The gas pressure regulator shall be equipped with a vent limiter or a vent line.

4.6 Operating and shut-off valves

- 1) Valves shall be rated for the application, including pressure, temperature, fluids contacted, and electrical ratings, if applicable.
 - a) Electrically operated valves shall comply with ISO 23551-1.
 - b) Valves for high pressure piping shall be tested in accordance with ISO 15649, instead of the external leakage test and the hydrostatic strength test of ISO 23551-1.
 - c) Valves for flammable fluids shall comply with ISO 23551-1.
- 2) Fuels supplied to the fuel cell power system shall be supplied through fuel lines provided with at least one automatic safety shut-off valve. The safety shut-off valve can also be an operating valve. The closing time for a safety shut-off valve shall be no greater than 5 s.
- 3) If an emergency manual shut-off valve is deemed necessary according to 4.16, it shall be in a readily accessible location and shall not have more than 90° rotation from the open to the closed positions. Any key or tool shall not prevent access to the manual shutoff valve. The valve shall be securely mounted and shielded or installed in a protected location to minimize damage from vibration or collision.
- 4) Where a manual valve is used, the valve shall be indicated with a marking in accordance with Clause 7 3)f).
- 5) Electrical and other automatically operated safety shut-off valves shall fail in a safe position.
- 6) Electrical valves located in classified areas shall be rated for the area of classification.

4.7 Filters

Air and fluid filters shall be suitable for the application and readily accessible if required to be inspected, cleaned, or replaced.

4.8 Pumps and compressors

- 1) Air compressors and air vacuum pumps employed in the system shall comply with ISO 10442.
- 2) Water pumps shall comply with IEC 60335-2-41.

- 3) Chemical and gaseous hydrogen pumps and compressors shall be evaluated to the applicable material compatibility requirements, mechanical and electrical requirements of this document.
- 4) A flammable fluid compressor or pump with rotating or other type dynamic seals, shall be provided with adequate ventilation so that small releases of hydrogen under normal operating conditions shall not allow the concentration of hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified areas of the fuel cell power system during normal release.

4.9 Electrically operated pressure sensing and controlling devices

- 1) Pressure activated switches and transducers shall be rated for the application. A pressure regulating control for a flammable or combustible fluid shall be suitable for its classification and the fluid it contains.
- 2) The maximum operating pressure of a pressure limiting or regulating control shall not exceed 90 % of the operating pressure of a pressure relief device. An accessible and adjustable pressure regulating control that can exceed the limits of the system shall be reliably sealed at the maximum operating pressure at which it is intended to operate.

4.10 Ventilation to prevent the build up of flammable gases

- 1) A fuel cell power system shall be provided with adequate ventilation so that normal releases under normal operating conditions shall not allow the concentration of hydrogen to be above 25 % of the lower flammability limit (LFL) in the unclassified zones of the fuel cell power system. This normal release shall include nominal stack fuel leakage rates or fuel purges that can occur during operation.
- 2) The diluted concentrations of hydrogen exiting the fuel cell power system even during abnormal operation shall not exceed 25 % of the lower flammability limit (LFL).

NOTE See IEC 62282-3-100 or IEC 62282-5-100.

- 3) The extent of a flammable region at a source of limited release (dilution boundary) shall be determined through appropriate analysis as outlined in IEC 60079-10-1.
- 4) Equipment located within the dilution boundary shall be suitable for the classification. Reference can be made to IEC 60079-0.
- 5) Abnormal releases of flammable fluids shall not create a safety hazard in accordance with 4.16, and shall result in the appropriate action, including the prompt shut down of the equipment, if necessary, that will mitigate the hazard or prevent the creation of additional hazards.
- 6) Mechanical ventilation shall be provided to keep the dilution boundary of 25 % lower flammability limit (LFL), under conditions of normal release, away from the unclassified components. Failure of ventilation shall cause the fuel cell power system to respond in such a way that shall mitigate any hazard or prevent the creation of additional hazards in accordance with 4.16. This can include shutting off, either through the detection of high gas concentration or with ventilation interlock provisions.
 - a) Limited, localized volumes of hydrogen concentration within the fuel cell power system can momentarily exceed the 25 % LFL of the hydrogen, but it shall be determined, in accordance with 4.16, that this transient condition does not create a safety hazard.
 - b) Mechanical ventilation is not required if it can be determined that the flammable gas concentration level falls below 25 % LFL under any conditions of normal release.
- 7) If gas detection is employed as a critical safety component in the fuel cell power system, the gas detection system shall comply with IEC 60079-29-1 and IEC 60079-29-4. Gas detection systems shall be located where they can most effectively measure the accumulation of hydrogen within the fuel cell power system and monitor the ventilation output as determined necessary.
- 8) If gas detection is employed as a critical safety component in the fuel cell power system, it shall be located in a control circuit that complies with IEC 60730-1:2013, IEC 60730-1:2013/AMD1:2015 and IEC 60730-1:2013/AMD2:2020, Annex H, and in accordance with 4.15.1 of this document.

- 9) In case of hydrogen leakage, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. The safety hydrogen sensor shall remain operational provided this does not increase the risk. In case of hydrogen safety sensor failure, the shut down valve shall be automatically operated. Similarly, the electrical switch shall be automatically shut down. Considering battery and tank safety testing, the appropriate documents such as IEC 62619 should be applied.
- 10) Ventilation openings and ducts shall not become obstructed or compromised when the fuel cell power system is normally operated in the truck.
- 11) Fans, blowers, and other devices employed for the ventilation system shall be suitable for the application. If fans and ventilators are used as the primary safety mechanism to prevent the build-up of flammable gas, the failure of the ventilation system shall not create a safety hazard in accordance with 4.16. Fans shall comply with IEC 60335-2-80. Ventilators shall comply with ISO 21927-3.

4.11 Electrostatic discharge (ESD)

- 1) Hydrogen fuel containing parts and parts within classified zones (see 3.26) of the equipment shall be constructed of materials that do not promote static discharges.
- 2) The exposed portion of moving metal parts such as fan blades and wheels, located in classified areas of the system shall be made of, or covered with, medium brass, bronze, copper or aluminum with hardness not more than Rockwell B66. Energy storage components such as batteries or ultracapacitors, and major power electronics components, such as fuel cell stack module, shall have their external conductive cases equipotentially bonded.
- 3) Components with non-current carrying metal parts and cases located in classified zones within the equipment shall be equipotentially bonded.
- 4) When a self-contained fuel cell power system is installed in a truck, a conductive path shall be provided between the fuel cell equipment components requiring equipotential bonding and the chassis of the truck.
- 5) Any fuel receptacle on the fuel cell power system provided for refuelling shall be equipotentially bonded to the fuel cell power system chassis.
- 6) Markings and instructions regarding the hazard involved with the buildup of static discharge and the means to mitigate this hazard shall be in accordance with Clause 7 3)d) and 8.4 2).

4.12 Discharges including methanol emissions and waste materials

- 1) The fuel cell power system shall be constructed so that waste materials, including water, are not exhausted, discharged or leaked in a manner that could create unsafe conditions.
- 2) Emissions from methanol fueled fuel cell power systems shall not exceed safe limits. Compliance is determined by the emission of effluents test of 5.16. Systems shall be designed to prevent emissions from entering the passenger compartment of the end use industrial truck application.

4.13 Enclosures

- 1) A fuel cell power system shall be enclosed for protection from access by persons to electrical parts, safety circuits, hazardous moving parts, hot surfaces, and other parts that can be a risk of injury.
- 2) Openings in a fuel cell power system enclosure of hazardous parts shall be located and sized to provide adequate protection from access to hazardous parts complying with a minimum IPXXB or IP2X minimum rating as outlined in IEC 60529.
- 3) An external enclosure for a fuel cell power system provided with an IP rating in accordance with Clause 7 2)) shall comply with the rain test in 5.17.1.
- 4) An external enclosure shall comply with the test of 5.18.1, unless the required protection is provided by the truck for an integrated fuel cell power system.
- 5) Non-metallic enclosure materials shall be flame rated V-1 minimum in accordance with IEC 60695-11-10 or shall comply with the test for thermoplastic materials in 5.19.
- 6) Any thermoplastic enclosure of a fuel cell power system shall be suitable for the range of temperatures that it is subjected to during use.

- 7) The system enclosure shall be designed to prevent the accumulation of liquids inside the enclosure. Drains are one potential means for compliance.

4.14 Electrical system

4.14.1 General

- 1) Electrical components shall be rated for the application and conform to the appropriate document for those components. They shall be located and secured so that they are not adversely affected by vibration, temperature, environment and other effects during normal operation of the fuel cell power system.
- 2) If electrical equipment internal to the fuel cell power system is located in hazardous zones, it shall be identified and managed according to IEC 60079-0.
- 3) EMC is subject to regional requirements. See ISO/TS 3691-7 and ISO/TS 3691-8.

4.14.2 Internal wiring

- 1) Internal wiring shall consist of any of the following:
 - a) general-use wire specified in IEC 60364;
 - b) appliance-wiring material of one or more of the types specified in Table 1.
- 2) The wiring shall be considered with respect to the temperature and conditions of service to which the wiring is to be subjected in the end truck installation.
- 3) At the connection to a component, wiring is permitted to extend beyond the braid for a length of no more than 254 mm.
- 4) Appliance-wiring material having a thickness of insulation less than the minimum acceptable value specified in Table 1 is permitted for a particular application, provided the insulation is considered with respect to temperature and conditions of service and is equivalent to one of the materials specified in Table 1.
- 5) A bare conductor is permitted to be insulated with insulating tubing.
- 6) Wiring shall be protected against mechanical damage by:
 - enclosing it within the fuel cell power system enclosure for self-contained fuel cell power systems, and
 - enclosing it within the body of the truck for integrated fuel cell power systems.
- 7) A conductor connected to a moving or movable part that cannot be protected, shall be designed for the intended use and shall comply with the test requirements in this document. Consideration shall be given to the resistance of the conductor to damage resulting from flexing, abrasion, or impact. Flexible metallic conduit is to be used only for flexible connections subject to small and infrequent movements.
- 8) Wiring connections to a continuously moving part, or a part for which the degree of movement is appreciable, shall be in accordance with IEC 60227-5.
- 9) The tubing can be omitted from exposed moving conductors that are readily visible to the operator and are, therefore, subject to replacement when damaged. The maintenance manual shall include instructions regarding inspection of these conductors for replacement when damage occurs in accordance with 8.2 5).
- 10) All of the connections shall be mechanically secure and shall provide electrical contact without stress on connections and terminals. A connection shall be provided with insulation equivalent to that on the wires involved.
- 11) A hole, through which insulated conductors pass, shall be provided with a smooth, rounded bushing, or shall have smooth, rounded surfaces upon which the insulated conductors may bear.
- 12) Wireways shall be smooth and free from sharp edges, burrs, fins, or moving parts that can damage wiring.
- 13) An internal-wiring connection shall be made with a solder lug or pressure terminal connector.

- 14) Control wiring and other small conductors, which are connected by crimped or soldered special-type lugs or eyelets including barrel terminals or by ultrasonic welding and that are insulated in accordance with 7), comply with the intent of this requirement.
- 15) A terminal lug shall be arranged so that in any position it cannot contact either the metal enclosure and non-energized accessible metal parts or other electrical circuits, or the shank of the lug shall be provided with insulation equivalent to that on the conductor.

Table 1 – Appliance-wiring material

Wire insulation	Minimum acceptable average insulation thickness mm
Rubber, neoprene or thermoplastic (PVC)	0,38 plus an impregnated braid, or 0,75 without a braid

4.14.3 External wiring

- 1) An external electrical output lead shall be of a size and capacity such that for a rated power output, the insulation temperature does not exceed its rating at maximum ambient temperature. It shall be provided with insulation able to withstand flexing, handling, and impact at temperatures between 50 °C and –20 °C. If intended for exposure to extreme temperatures above 50 °C and at or below –20 °C, the lead shall comply with 5.22. The average insulation thickness shall be fixed in accordance with IEC 60227-3. The length of the lead and connector assembly shall be as short as practicable without interfering with the disconnecting operation and without placing stress on terminals when installed in the truck.
- 2) An external electrical output connector shall be rated for the output of the fuel cell power system. Live parts shall be recessed from the face of the connector to reduce the possibility of shorting. A removable portion of the connector shall be provided with means for being grasped during removal. The connector shall be located to provide mechanical protection when the fuel cell power system is installed in the end use.
- 3) External wiring shall be protected against mechanical damage by
 - a) enclosing it in the body of the truck,
 - b) enclosing it in a metal raceway such as armored cable, rigid metal conduit or electrical metallic tubing, or
 - c) protecting it with metal, phenolic composition, or other thermosetting material having equivalent mechanical strength and resistance to impact and having no greater combustibility than phenolic.
- 4) This enclosure or protection shall be such that any flame or molten material, which can be caused by an electrical disturbance in the wiring, cannot reach surrounding combustible material.

This requirement does not apply to flexible external leads that require flexibility for disconnection, output leads of the fuel cell power system for example, that comply with 1).

This requirement does not apply to leads that, if damaged, do not result in a hazard.

4.14.4 Emergency switching off requirements (disconnection) for connections for fuel cell power system

- 1) An emergency switching off control or battery connector when used as an emergency switching off device shall be accessible to the operator in the normal operating position at all times.
- 2) The emergency switching off device shall be capable of interrupting without danger the power supplies to all moving elements where an interruption does not increase the potential risk. It shall be capable of interrupting the normal maximum current (including motor starting current) by one of the following methods: