STANDARDS AND INTERNATIONAL CERTIFICATION SCHEME FOR EQUIPMENT USING HYDROGEN TECHNOLOGIES

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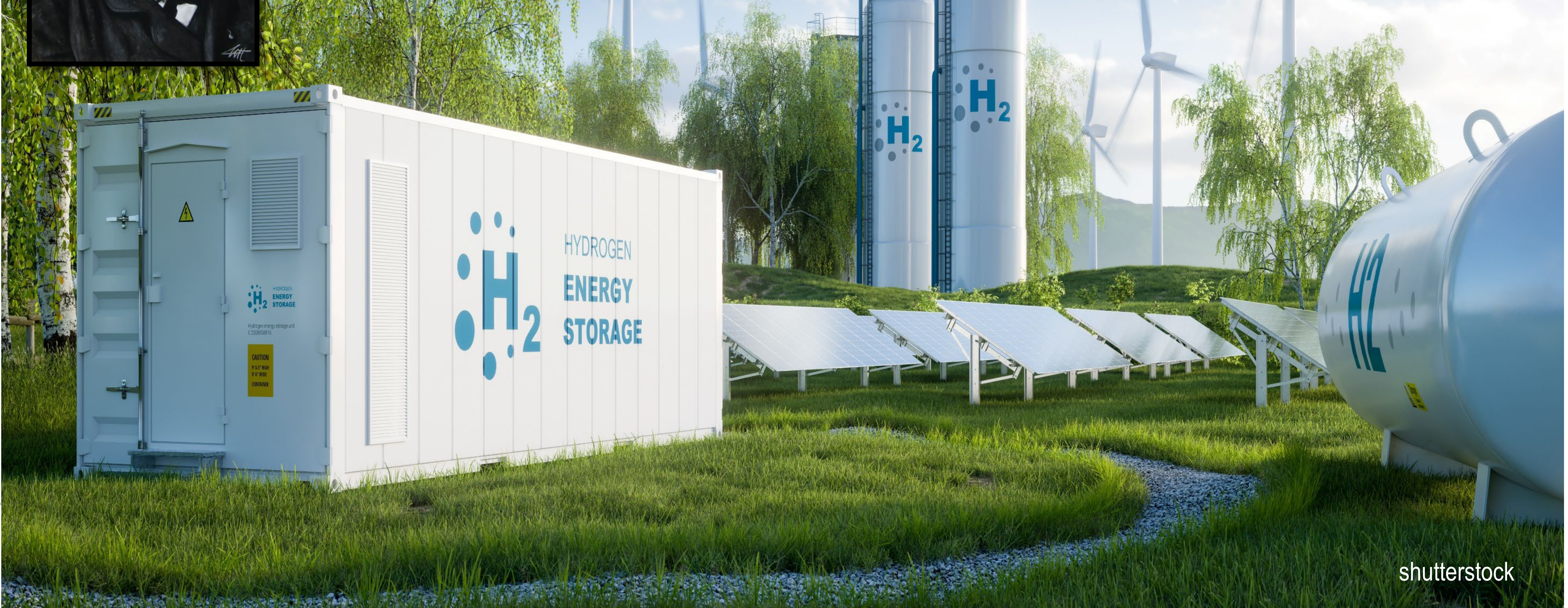
"water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable"

Jules Verne in The Mysterious Island

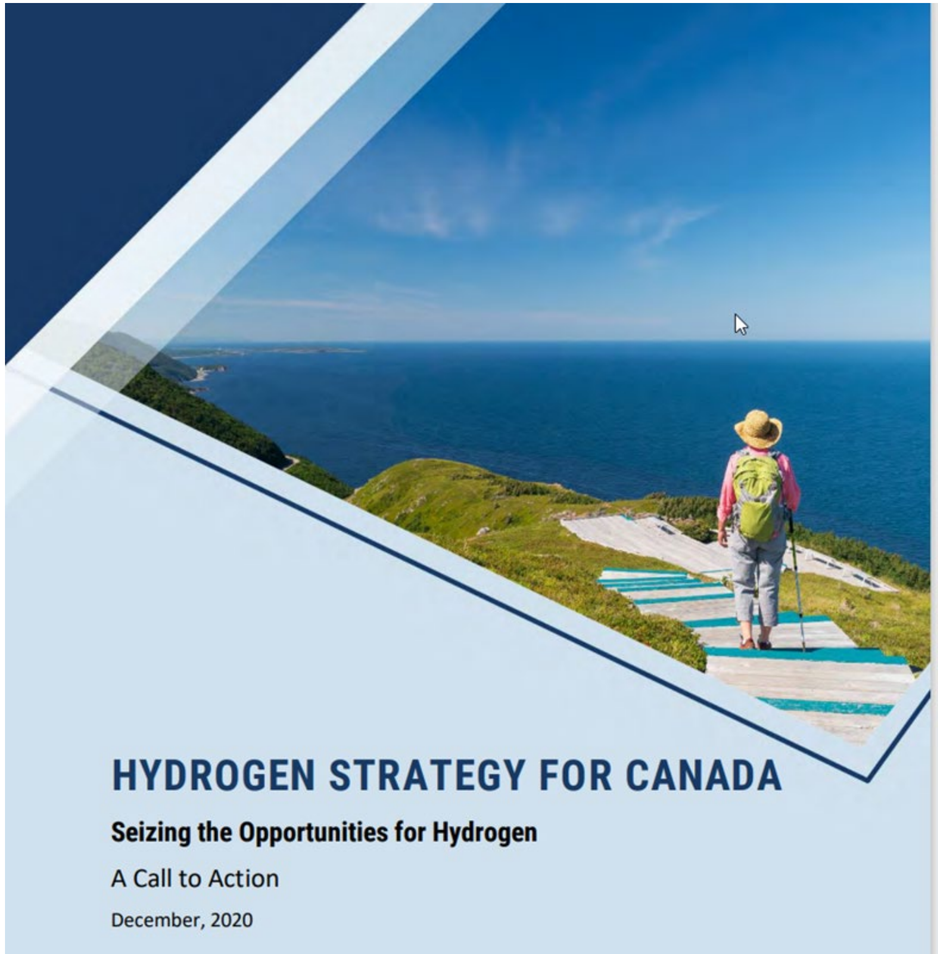


CANADIAN H2 STRATEGY: AWARENESS FOR SAFETY ISSUES IS CURRENTLY LACKING

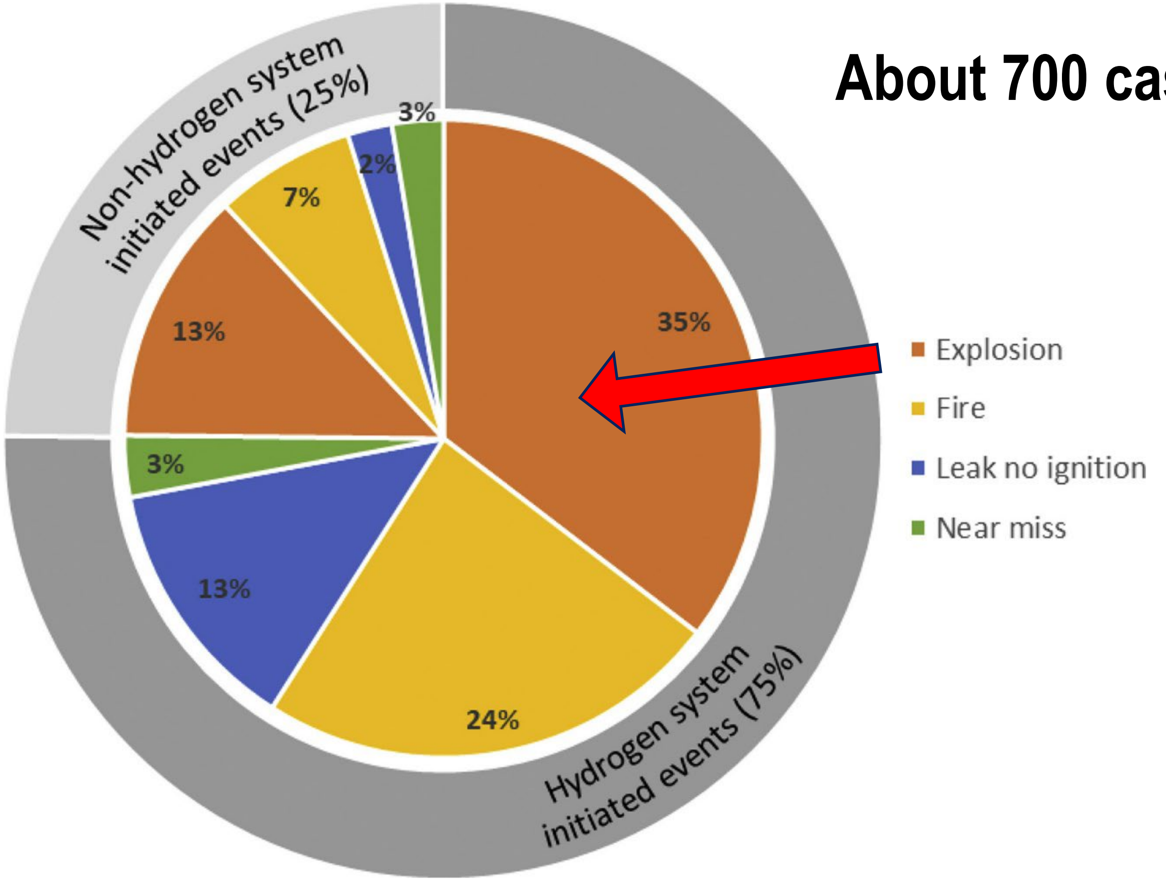
AWARENESS

There is currently a lack of awareness about the opportunities for hydrogen and around safety issues, both by the public, as well as within industry and government.

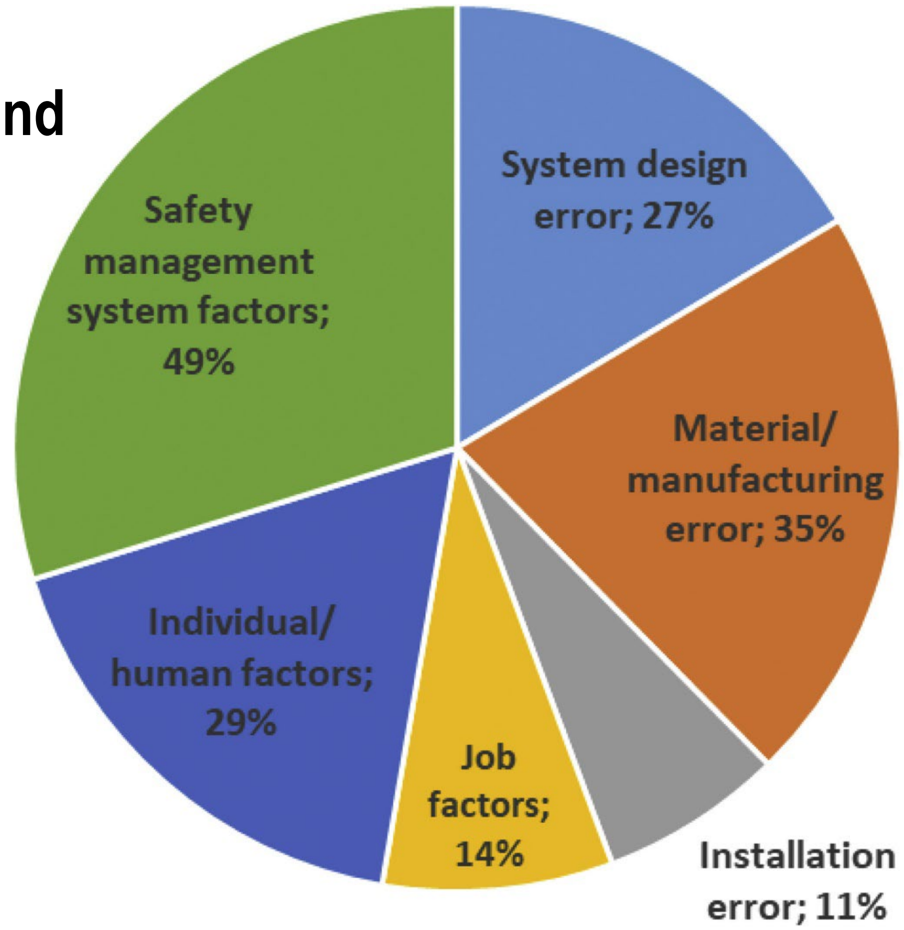
Limited domestic hydrogen deployments have further resulted in a lack of tangible case studies to increase awareness and support long-term planning and buildout. For example, mine safety and reliability must be successfully proven in the pilot stage before technology can be fully adopted.



HIAD 2.0 EUROPEAN HYDROGEN INCIDENT AND ACCIDENT DATABASE @ 2022 EUROPEAN HYDROGEN SAFETY PANEL (EHSP)



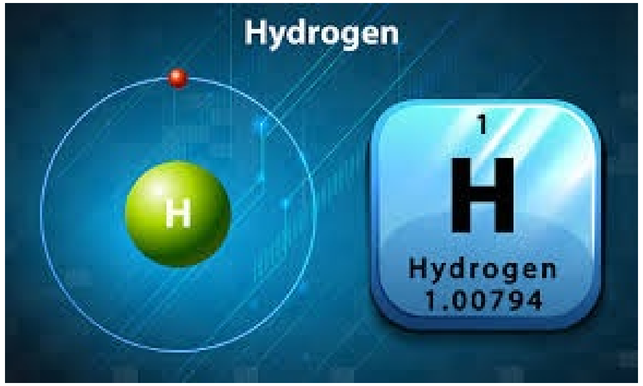
About 700 cases found



We., J. X. et al: Statistics, lessons learned and recommendations from analysis of HIAD 2.0 database; International Journal of Hydrogen Energy 47(2022)

TECHNICAL REPORT ISO/TR 15916: 2015

- Overview of hydrogen applications
- Basic properties of hydrogen
- Safety considerations for the use of gaseous and liquid hydrogen
- Team approach and education/training needed for the safe use of hydrogen
- Mitigation and control of hazards and risks
    - Deflagration and detonation
    - Oxygen enrichment
    - Gas detection (ISO 26142); fire detection
    - Many other aspects



Distran, Micropack

GENERAL SAFETY CONCEPT FOR HYDROGEN FACILITIES

RISK ANALYSIS AS THE STARTING POINT AND THE BASEMENT

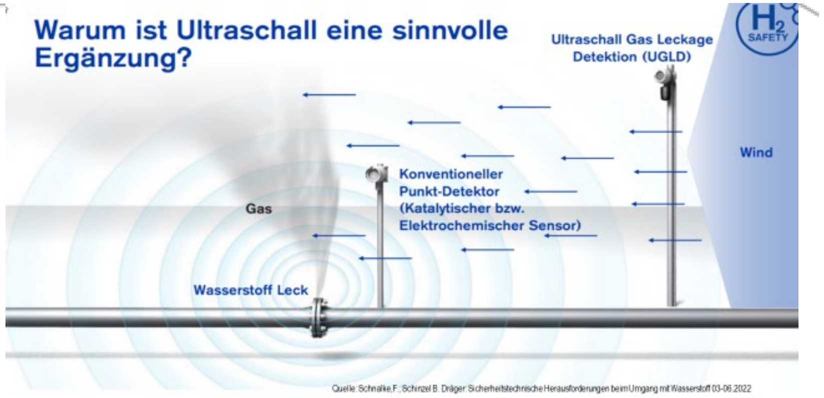
- The manufacturer must perform a risk analysis using one or more methods according to IEC 31010, Annex B, i.e.
    - HAZOP, fault tree analysis (FTA), FMEA, Markov analysis
- and/or ISO 12100 "Safety of machinery".
- Normal operation and relevant error conditions must be observed during this process
- When planning the system, the requirements of ISO 12100 must be followed.

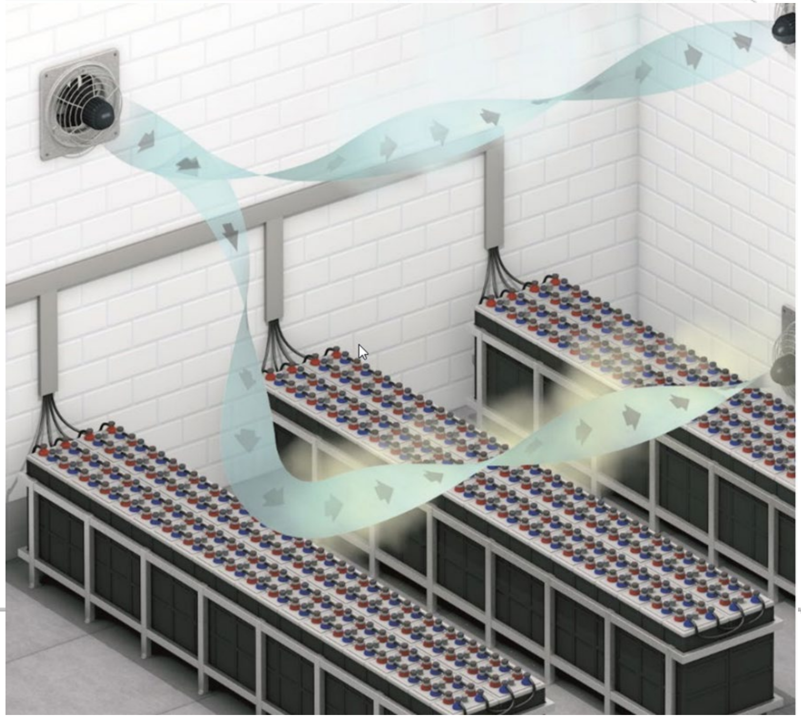
Source: Sunfire

1. PRIMARY PROTECTIVE MEASURES: PREVENTION OF THE FORMATION OF EXPLOSIVE ATMOSPHERES

1. Tightness of the systems
2. Adequate natural ventilation
3. Gas concentration monitoring
4. Switch on at > 25% LEL technical ventilation
5. Monitoring of gas concentrations at > 25% LEL

   Shutdown of the system



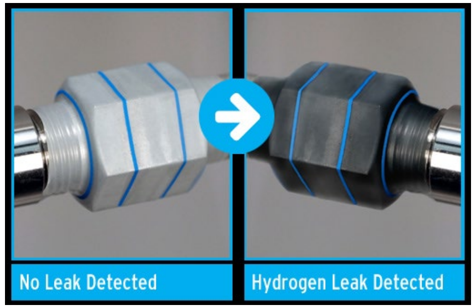


Maica/ Dräger

Reliability of all safety functions is important ! (SIL)

LEAK TIGHTNESS OF THE SYSTEM PARTS: EN 1127-1:2019: ANNEX B

- **Normal leak tightness**: No release is expected during normal operation; if this does occur, it is rare and for a short time.
- **Increased leak tightness**: No release at all is expected, and no explosive atmosphere can form in the surrounding environment
- One potential way to achieve increased leak tightness is the use of continuous gas monitoring with an appropriate degree of functional safety
- **ISO 26142**: Stationary gas detection equipment for H2



OLDHAM, Drager

EXPLOSION PROTECTION BY AVOIDING IGNITION SOURCES

- When it comes to Ex protection, zone classification as per IEC 60079-10-1 must be performed and, if necessary, ignition protection methods as per IEC 60079-0 ff. must be implemented.

- The specific Ex conditions in oxygen-rich atmospheres must be observed.

- Appropriate Emergency stop and shut down measures must be installed.

NEL

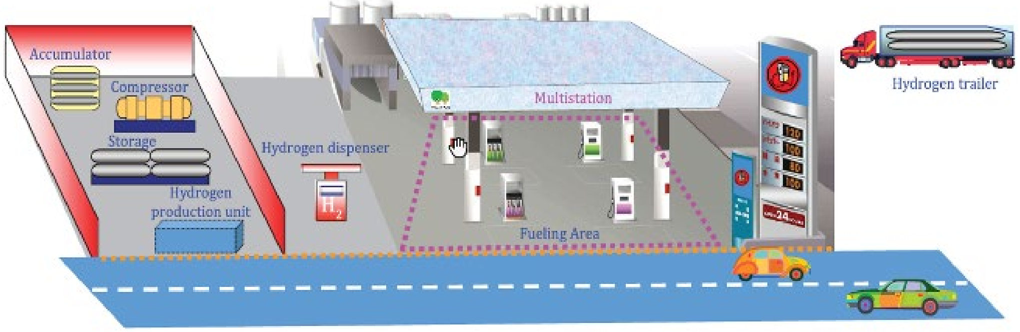
IMPORTANT MECHANICAL REQUIREMENTS

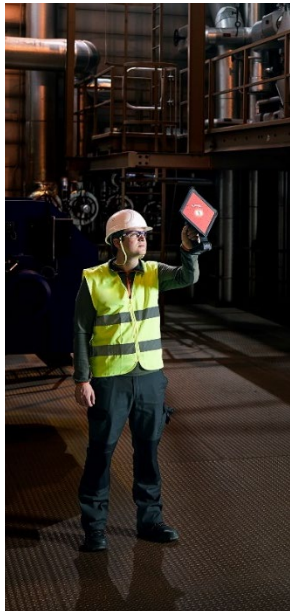
- Material must be suitable for all operationally
  - mechanical
  - thermal
  - electrical
  - chemical loads
- Enclosures must have sufficient fire resistance
- Adequate protection against electrostatic charging
- Pressure bearing components must have the required strength
- Protection against external influences

faz

COMPETENCE FOR CORRECT PLANNING, INSTALLATION, OPERATION, INSPECTION AND MAINTENANCE IS REQUIRED!

- Zone classification as per IEC 60079-10-1
- Installation as per IEC 60079-14
- Types of protection with reference to IEC 60079 ff. and IEC 80079-36/37
- Inspection and maintenance as per IEC 60079-17

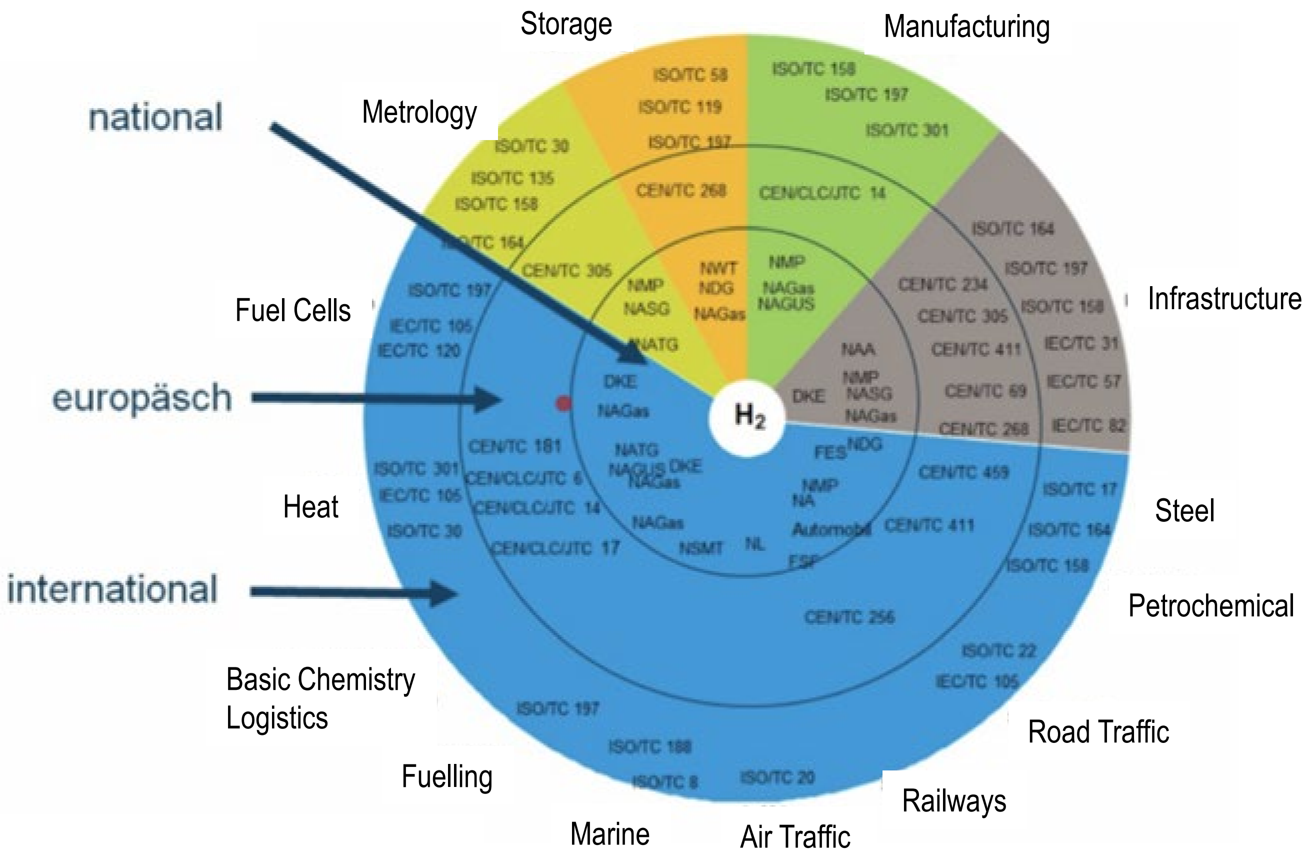




Distran, bmvi

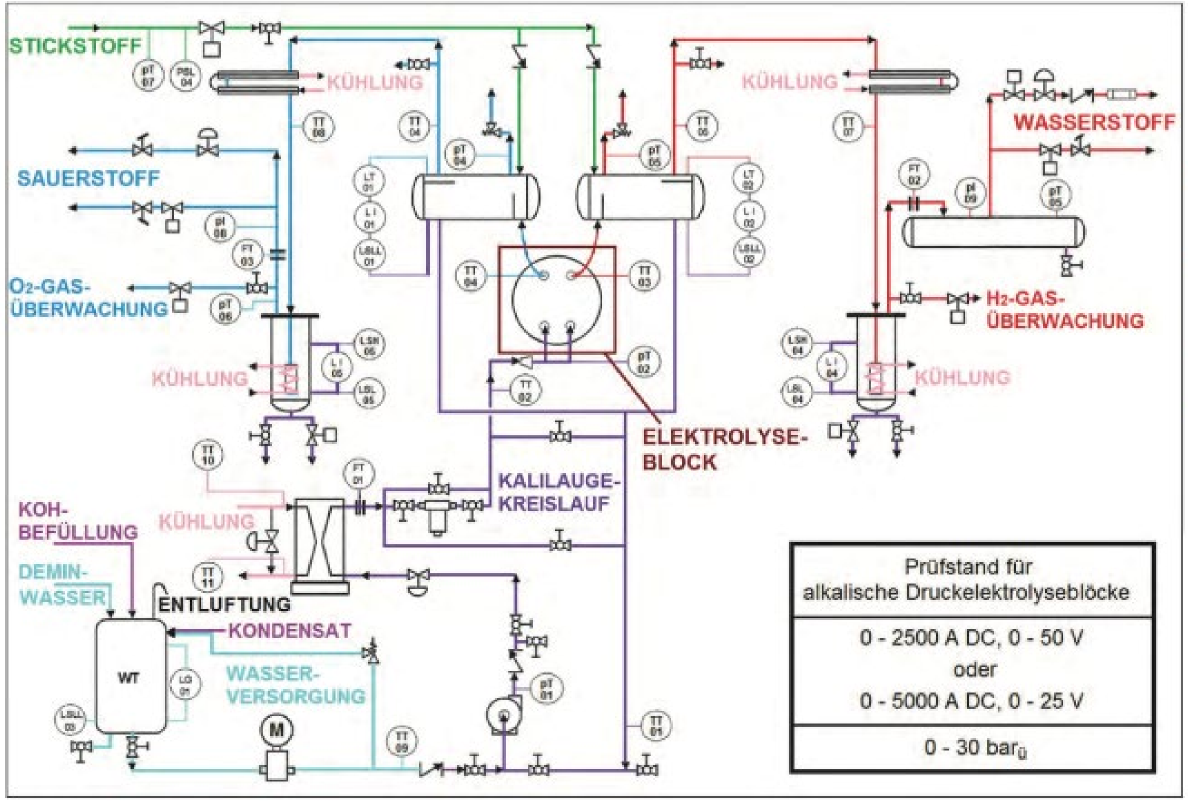
IMPORTANT HYDROGEN SAFETY STANDARDS

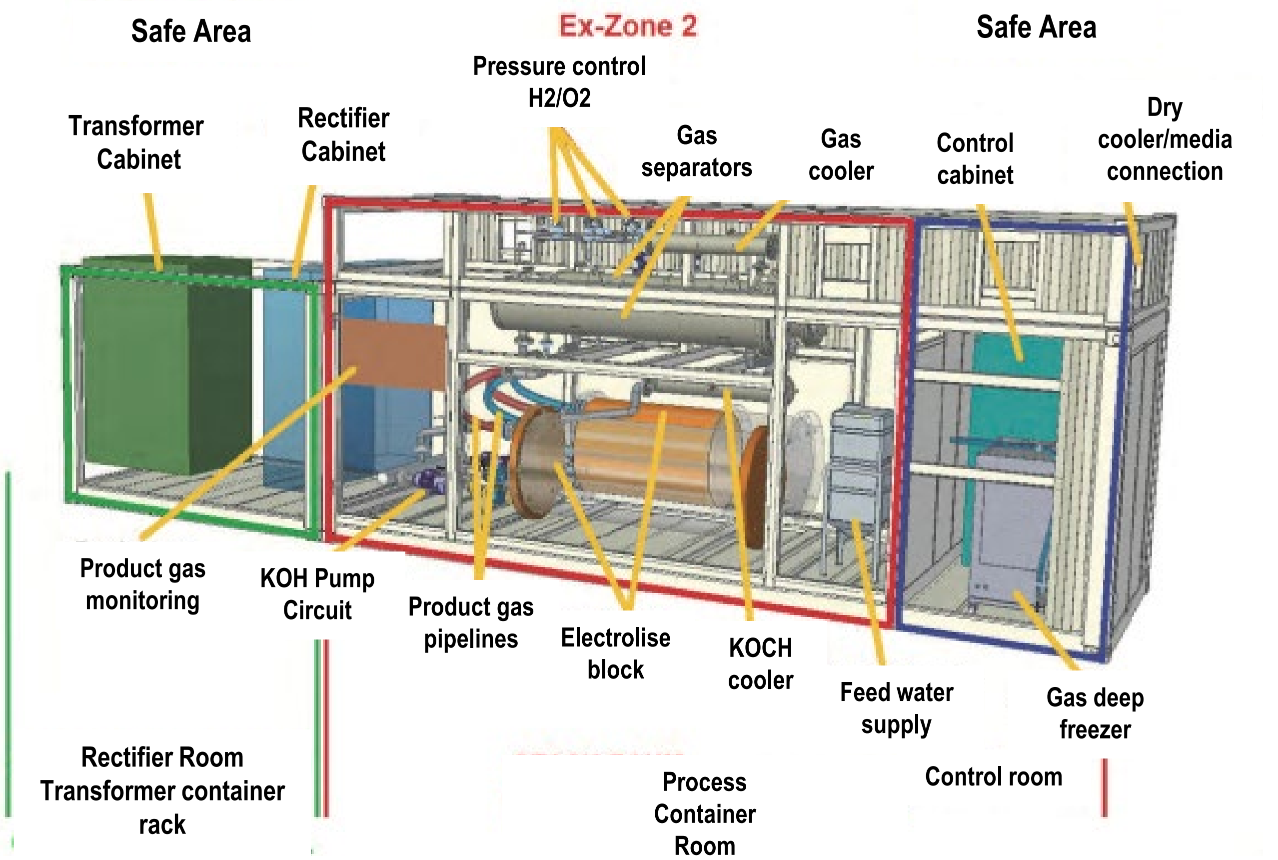
HYDROGEN STANDARDS MAP



Source: Fraunhofer

ISO 22734: HYDROGEN GENERATORS USING WATER ELECTROLYSIS – INDUSTRIAL, COMMERCIAL AND RESIDENTIAL APPLICATIONS (2019)



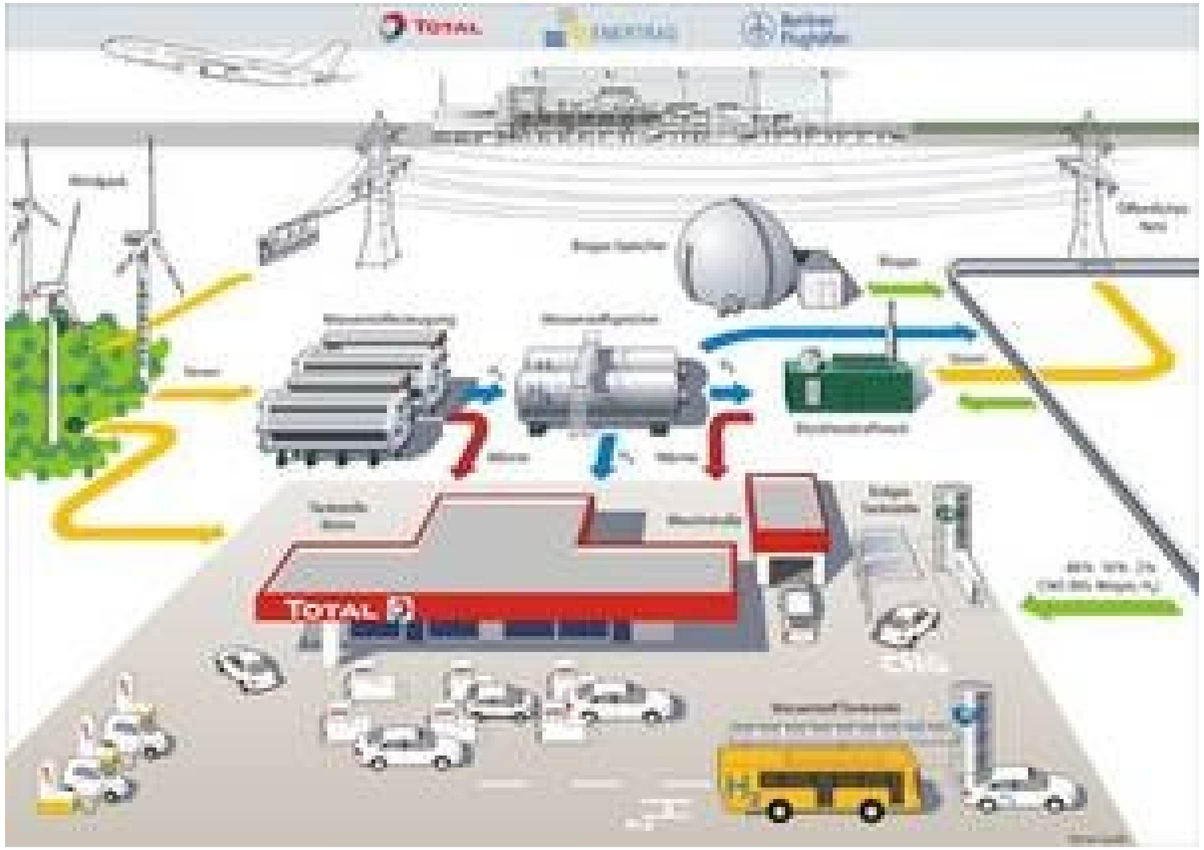


Quelle:ZLS

ISO 19880-1 FF:2020 HYDROGEN FUELLING STATIONS

The following should be considered potential sources of hazards:

- Local H_2 production units
- The entire H_2 supply system (from an external perspective)
- Compressors
- Tanks
- Non-welded pipeline connections
- Hydrogen distribution up to the vehicles



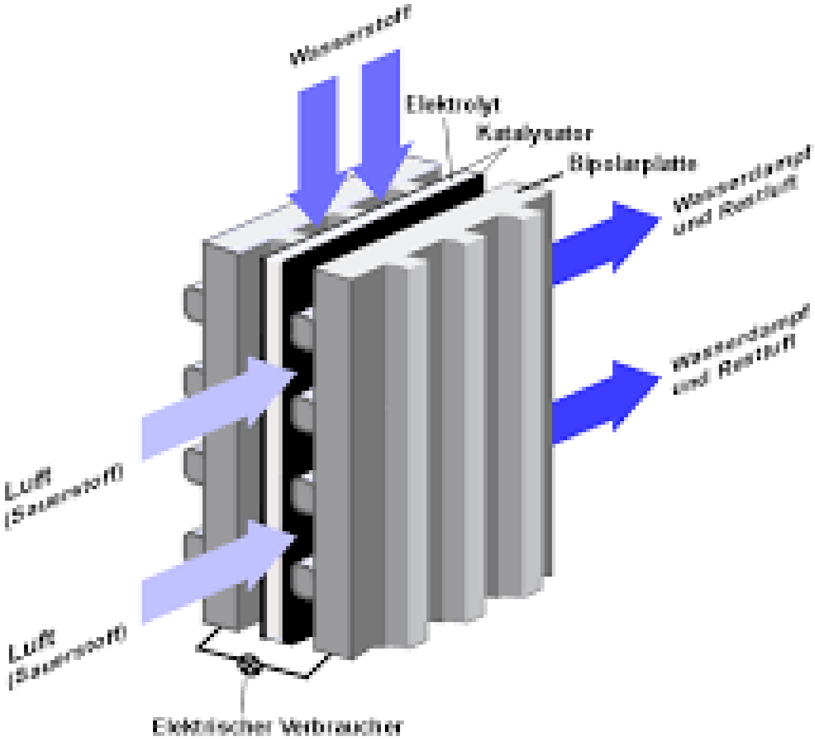
Leuna - echo

All areas must be subjected to a systematic risk assessment

IEC STANDARDS (TC 105): IEC 62282-2-100 (CDV)

FUEL CELL TECHNOLOGIES – PART 2 -100: FUEL CELL MODULES

- **A comprehensive risk analysis shall be done by the manufacturer including a written documentation of this:**
  - Identification of all reasonably foreseeable hazards (see Appendix A with a list of typical hazards)
  - Evaluation of the probability of occurrence and ist foreseeable severity
  - Elimination of all risks or reduction to an acceptable level.
- **Alternatives for risk reducing measures:**
  - Inherent safe constructions and/or
  - passive control of energy release in safe areas (busting discs, release valves) and/or
  - safety related control functions
  - handle residual risks by means of organizational methods (operations instructions, warning labels etc.)



Chemgapedia.de

IEC 62282-3-100: 2020 & 62282-5-100:2020

SAFETY OF STATIONARY/PORTABLE FUEL CELL ENERGY SYSTEMS

- Risk analyses such as for fuel cell modules
- Same requirements for material properties and process stability as required for modules
- Hazards due to the accumulation of flammable atmospheres must be eliminated!
- Areas containing sources of combustible gases or vapors must be identified and classified
- In these areas, dilution to a maximum fuel concentration of 25% of the OEL is ensured and monitored to the greatest possible extent
- This is not possible in spaces classified as **hazardous areas**.

Fuel Cell Works.com

IS ALL THE EFFORT FOR SUCH A HYDROGEN SECURITY CONCEPT JUSTIFIED? WHAT EXPERIENCES HAVE BEEN MADE SO FAR WITH REGARD TO THE DANGERS OF H2 APPLICATIONS?

08. August 2023 Graz/Austria

Explosion of a Hydrogen Tank Close to the Autobahn.

One person injured

Heavy damages in the facility.

STEIERMARK LEBEN SPORT **KLEINE ZEITUNG** GRAZ & UMGEBUNG EINLOGGEN

Wasserstofftank neben Autobahn explodiert, Mann (39) verletzt

Auf dem Areal einer Firma in Lebring ereignete sich Dienstagmittag eine Explosion. Ein Mitarbeiter wurde dabei leicht verletzt. Die Polizei gab am Nachmittag Entwarnung, die Gefahr sei aber noch nicht gänzlich gebannt.

Durch die Wucht der Explosion wurde ein Teil der Anlage schwer beschädigt

WHAT DOES IECEX DO TO ESTABLISH A SUFFICIENT LEVEL OF SAFETY FOR HYDROGEN APPLICATIONS?

Goal 1: Minimize potential human error:

- IECEx added Hydrogen specific competence elements to the Recognized Training Provider (**RTP**) Program and
- Established Unit 11: Basic knowledge of the safety of hydrogen systems
- Unit 11 works in conjunction with two or more standard Units of OD 504
- Unit 11 refers directly to ISO/TR 15916

AGU

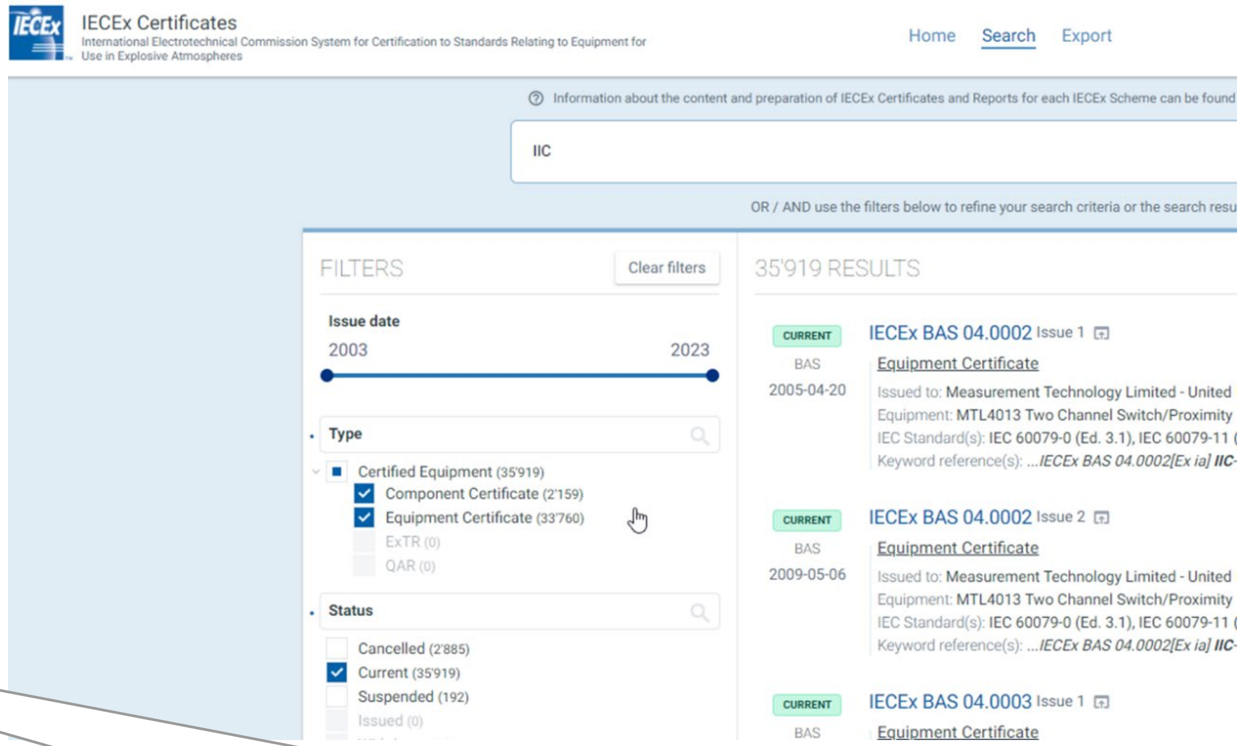
EXAMPLE: CANADIAN HYDROGEN INSTALLATION CODE – 4.2 INSTALLER QUALIFICATIONS, AND OPERATOR TRAINING

- Only qualified personnel shall be responsible for the installation of hydrogen equipment covered by this code.
- Upon completion of an installation, the installer shall train the system operator on the proper and safe use of all hydrogen equipment covered by this code.
- At a minimum, system operator training shall cover basic hydrogen properties; safety aspects, including the safe handling and operation of hydrogen systems…

WHAT DOES IECEX DO TO ESTABLISH A SUFFICIENT LEVEL OF SAFETY FOR HYDROGEN APPLICATIONS?

Goal 2: Develop systems that remain robust in the event of human error:

- IECEx keeps **35 919 current IIC** – Product certificates in the online database
- OD 290 is the basis for harmonized procedures for IECEx certification of equipment, components and systems **associated with the production, dispensing and use of gaseous hydrogen**



OD 290 refers closely to the relevant Hydrogen standards like ISO 19880-X and to IEC 60079-46: Equipment assemblies

EXAMPLE: CERTIFICATION REQUIREMENTS

5 HYDROGEN EQUIPMENT

5.1 HYDROGEN EQUIPMENT TO BE INSTALLED

Hydrogen-generating equipment for non-process end use, hydrogen utilization equipment, hydrogen-dispensing equipment, hydrogen storage containers, hydrogen piping systems and their accessories shall be certified or approved prior to installation.

7.7 COMPRESSORS AND COMPRESSOR PACKAGES

7.7.1 General

Only compressors that are designed for hydrogen systems shall be used.

Compressors that are an integral part of certified or approved hydrogen-generating equipment need not comply with the provisions of Clause 7.7.

shall be certified

7.8.1.3 Subject to the approval of the AHJ, stationary containers for compressed gaseous hydrogen storage originally intended for transportation and onboard use shall be certified to one of the following documents:

a) CSA B51, Part 2;

b) ISO 11119;

c) ISO 19881;

Dispensers shall comply with the requirements of the document CSA/ANSI HGV 4.1. Dispenser validation testing for light-duty vehicles shall be performed in accordance with the document CSA/ANSI HGV 4.3.

NOTE — The document CSA HGV 4.9 focuses on hydrogen key fuelling station components and protocols by setting requirements and referencing appropriate standards, e.g., documents SAE J2601 for hydrogen fuelling protocol, SAE J2799 for communication with a hydrogen-fuelled vehicle, CSA/ANSI HGV 4.1 for hydrogen dispensers and CSA/ANSI HGV 4.3 for hydrogen dispenser validation testing.

THANK YOU VERY MUCH FOR YOUR ATTENTION

THE STRONGEST LINK.

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