MOVET

Centro d'iniziativa per i MOtori, VEicoli e Tecnologie

Il ruolo dell'idrogeno nella transizione tecnologica ed ecologica dell'energia

17 dicembre 2021

Idrogeno e sicurezza: prevenzione e mitigazione del rischio

IN SUPREMÆ DIGNITATIS · 1343 ·

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The European Hydrogen Safety Panel (EHSP)

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EHSP role: to provide within FCH-JU independent safety expertise, objective information, education and training in different forms for various groups of stakeholders and support the anticipated upscaling of hydrogen energy application

- To assure hydrogen safety is adequately managed
- To promote and disseminate hydrogen safety culture

TF1
Project
Level

TF2
Program
Level

TF3
Data
Collection

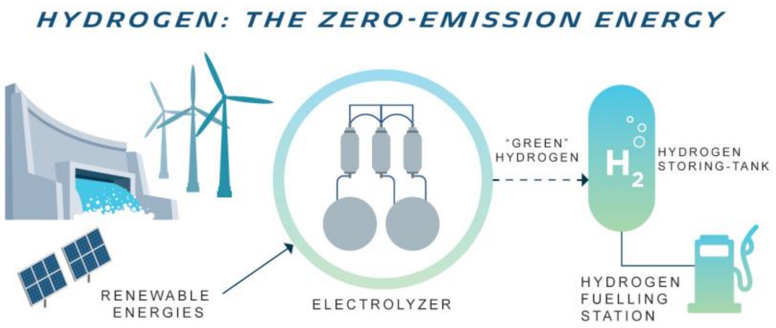
TF4
Public
Outreach

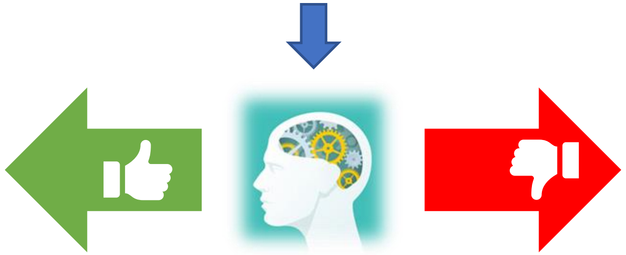
Hydrogen safety *(safety = freedom from risk which is not tolerable)*

RISK = probability x damage

defined individually and/or by society

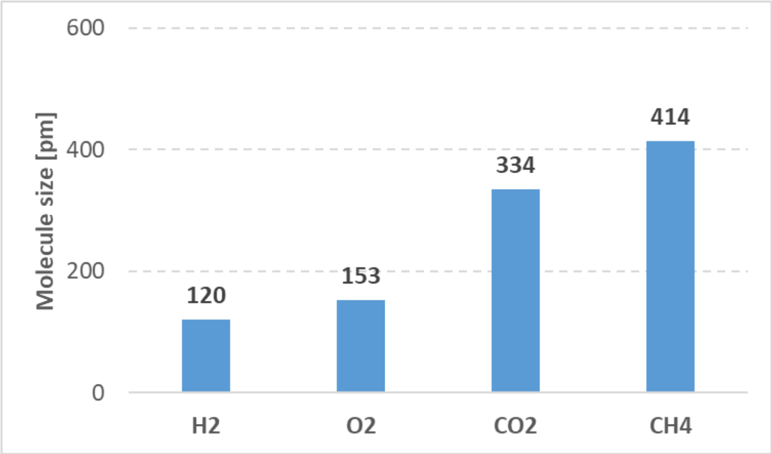
- **Hydrogen safety engineering practices in the production, storage, distribution and use of hydrogen**
    - ➢ essential for the widespread acceptance of hydrogen and fuel cell technologies
- A catastrophic failure could damage the **public's perception of hydrogen and fuel cell technologies**
    - ➢ implying a considerable loss of public and private investment

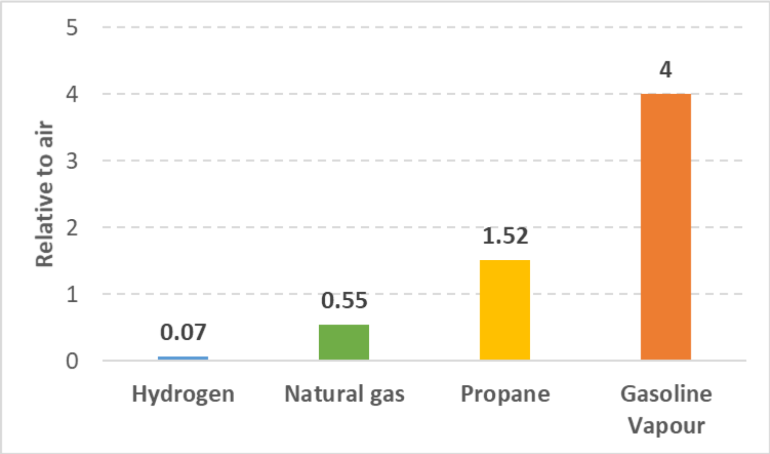


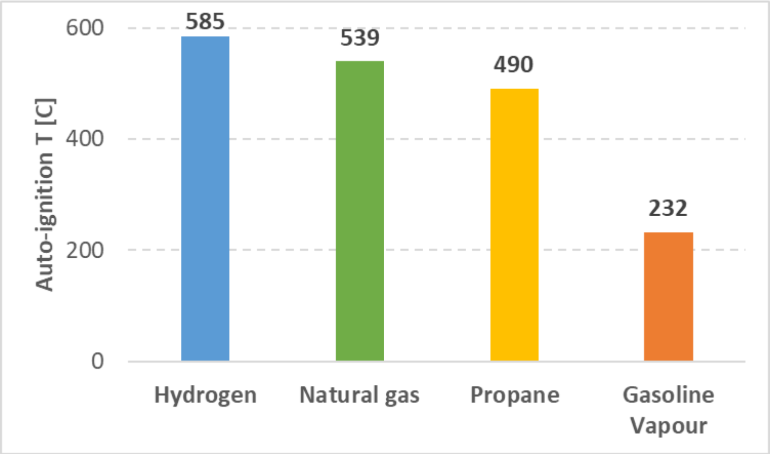


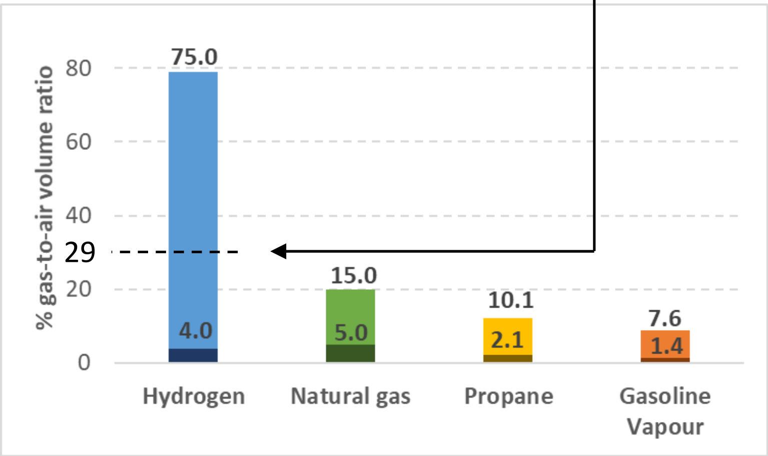
Minimize potential hazards and associated risks to prevent impacts on people, property and environment

Hydrogen properties: a comparison

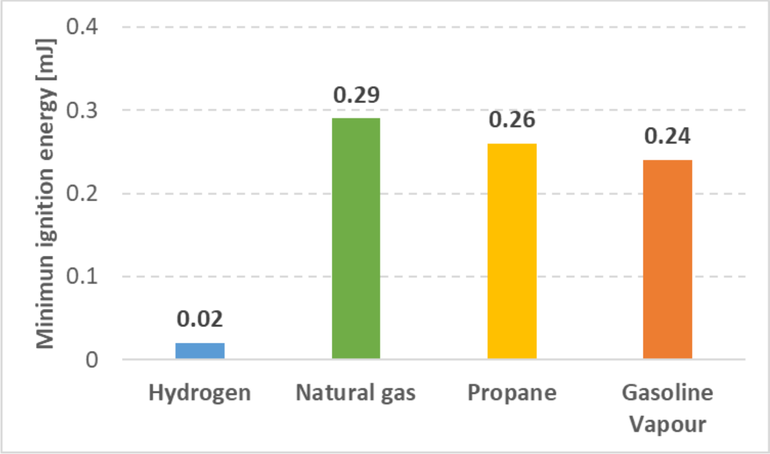




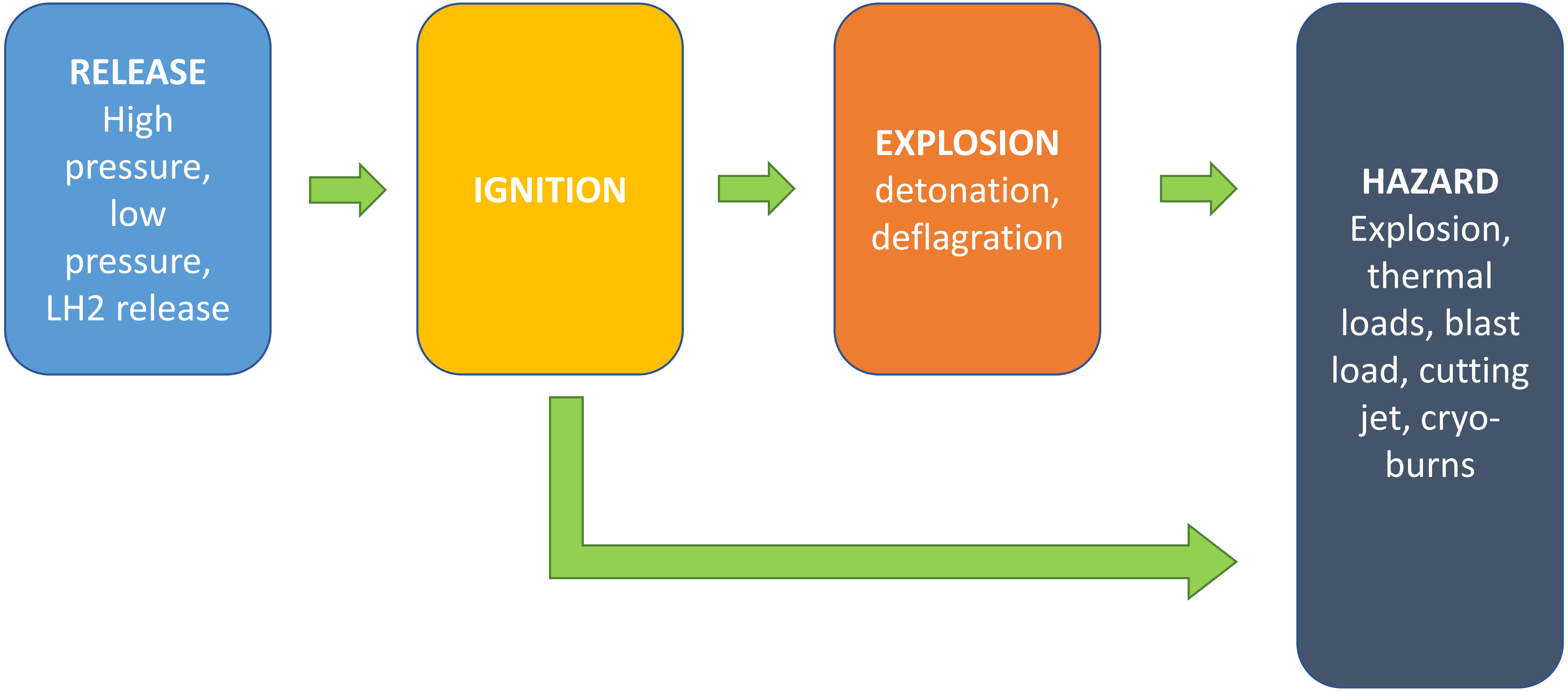




Under optimal combustion condition



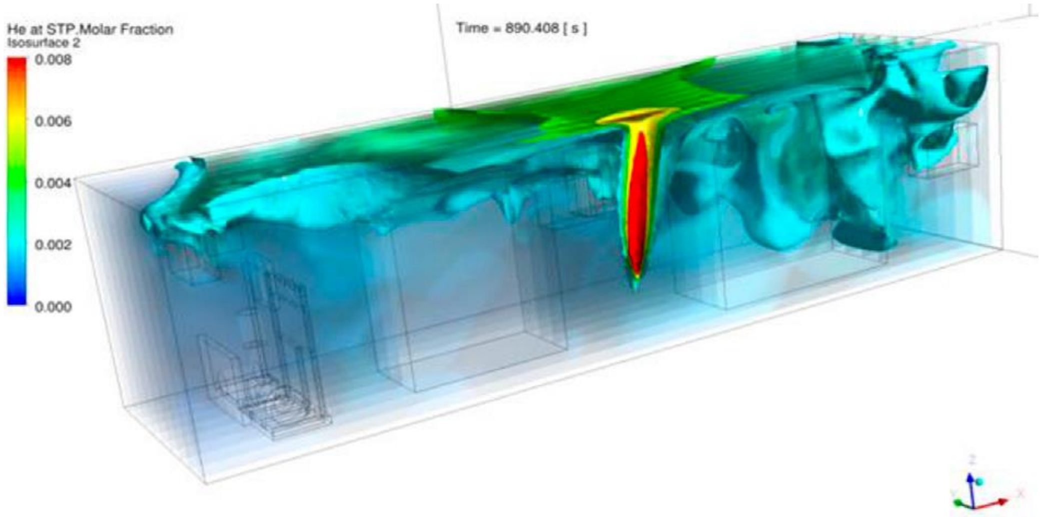
Potential consequences and hazards associated with a H2 release



Hydrogen release

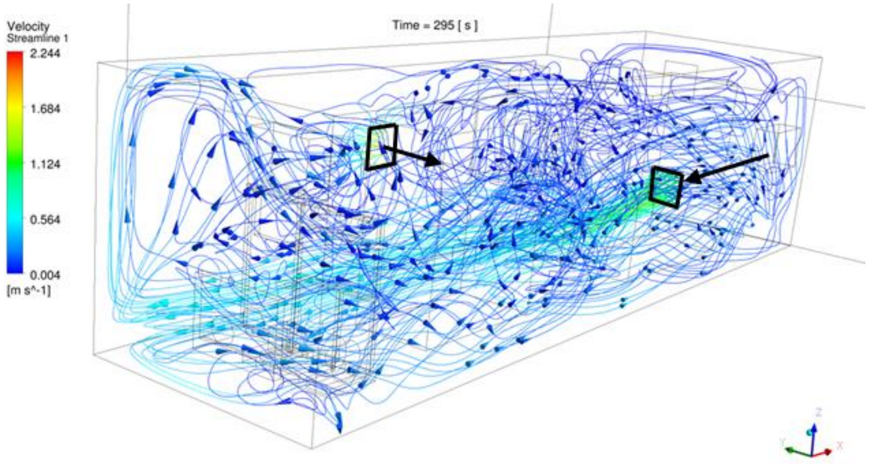
- Because gaseous hydrogen consists of such a small molecule, **very small leaks are common** (e.g. permeation)

- **In properly designed systems very small leaks do not present a problem** as the tiny amount of hydrogen released will not be enough to cause a flammable mixture in air
  - ➢ The releases may originate from: valves, connections, pinholes in pipes, a full-bore pipe rupture (worst-case scenarios); cylinders, pumps, regulators, etc.
  - ➢ Hydrogen releases may occur both indoors and outdoors
    - ➢ **Only when hydrogen gas can accumulate over time in a confined area will a risk of a flammable mixture or asphyxiation arise**



- The releases can be unignited (non-reacting) or ignited (reacting)

Ventilation



Passive ventilation

- Designing passive ventilation: ceiling and roof configurations to ensure that a hydrogen leak will be able to dissipate safely

- **Inlet openings** should be located at **floor level** in exterior walls
- **Outlet openings** should be located at the **high point of the room** in exterior walls or roof

Active (mechanical, forced) ventilation

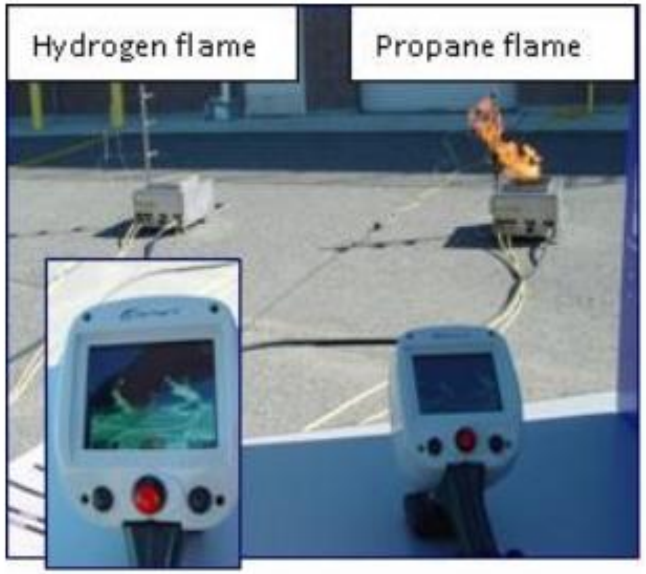
- Air flow is selected to ensure **hydrogen concentration is < 25% of the lower flammability limit** (i.e. 1% hydrogen by volume)
- No practical ventilation rate can effectively disperse hydrogen from a massive release from a pressurized vessel, pipe rupture, or blowdown

✓ If active ventilation systems are relied upon to mitigate gas accumulation hazards
  ➢ procedures and operational practices should ensure that the system is always operational when hydrogen is present

✓ Hydrogen equipment and systems should be shut down if there is a loss of the ventilation system.

Hydrogen flames

- Hydrogen burns with a pale blue **flame** that is **nearly invisible in daylight**, so it is almost impossible to detect by the human senses
  - ➢ Impurities such as sodium from ocean air or other burning materials will introduce color to the hydrogen flame
- Hydrogen fires have **low radiant heat**, so you can't sense the presence of a flame until you are very close to it
- Combustion can't occur in a tank that contains only hydrogen. Oxygen (or air) and an ignition source are required for combustion to occur



Leak detection

Instrumented hydrogen leak detection systems can be used to enhancing safety of the facility.

Instrumented leak detection techniques include:

- ✓ Hydrogen (and flame) detectors installed where leaking hydrogen is likely to concentrate
- ✓ Monitoring piping pressures or flow rates changes
- ✓ Locating hydrogen piping within another pipe (double containment) and monitoring the annulus for leaks

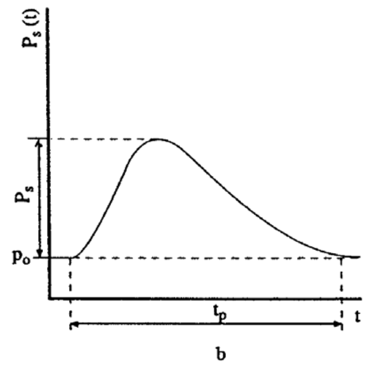
Detectors should be permanently installed in indoor facilities.

- ✓ **Locate detectors** where leaking hydrogen will be accumulate such as:
  - **Stagnation points** near the ceiling where hydrogen can accumulate
  - **Low-velocity regions** of enclosure ventilation system
- ✓ Provide access to detectors for periodic calibration
- ✓ The sensitivity of the detector to other gases and vapors should be considered in the selection of the detector and should be explained to personnel
- ✓ Alarms are normally set at 1% hydrogen by volume (i.e. 25% of the lower flammability limit)

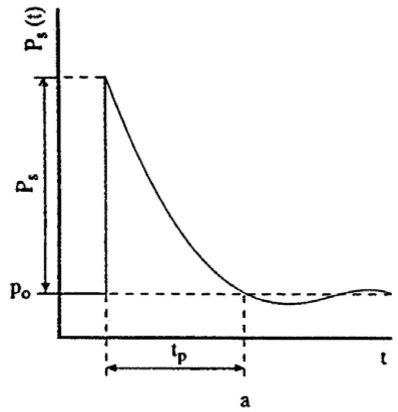
Hydrogen explosions

Hydrogen released in sufficient quantities can create a harmful overpressure which may result in direct hazards and indirect hazards from building damage or flying debris. Overpressures can occur as a result of unignited releases of pressurized gas or as a result of ignition of a cloud of released flammable gas.

- **Deflagrations (v<C)** in the open, in the absence of any obstacles
  - Typical propagation speed: at speed of 1-100 m/s
  - Typical overpressure: about 10 kPa
  - Deflagration in an enclosure can be mitigated by venting, the most cost-effective and widespread explosion mitigation technique.

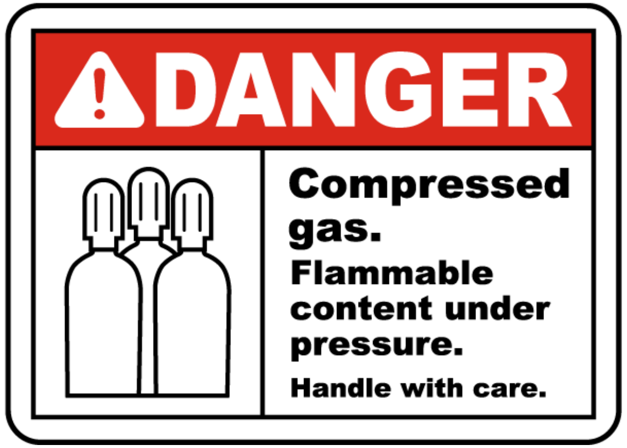


- **Detonation (v>C)** is a coupled shock and flame front structure which propagates with supersonic velocity
  - The speed of detonation wave depends on the stoichiometry of hydrogen-air mixture and ranges from 1600 to 2000 m/s (4<M<8)
  - Typical overpressure : 1000-1500 kPa.
  - Venting technique is not applicable to detonations as the pressure arrives to any location and affects a system and/or structural elements simultaneously with the detonation wave



Hydrogen safety, much like all flammable gas safety, relies on five key considerations:

- ✓Recognize hazards and define mitigation measures
- ✓Ensure system integrity
- ✓Provide proper ventilation to prevent accumulation
- ✓Ensure that leaks are detected and isolated
- ✓Train personnel

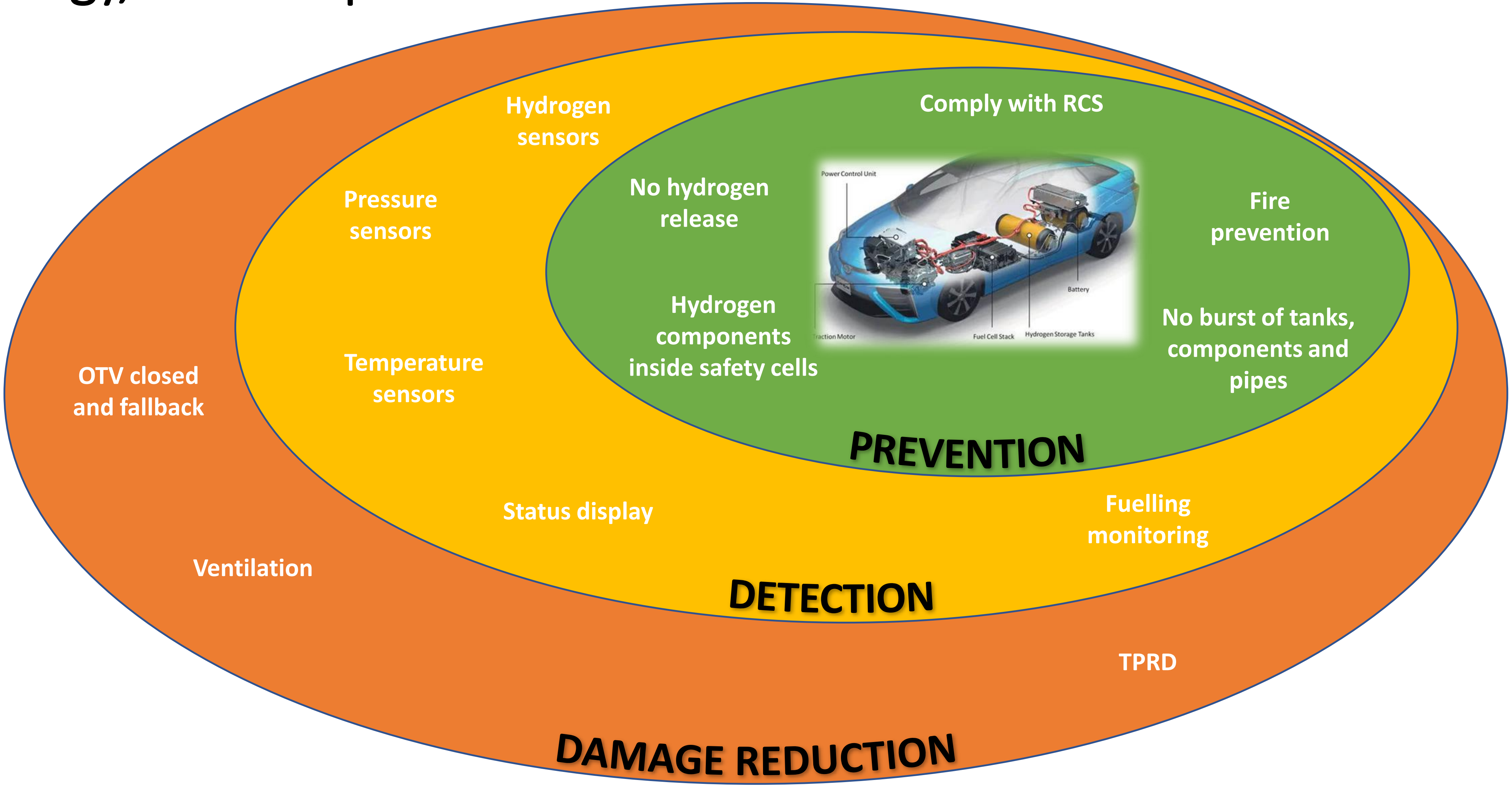


Facility Design and Construction

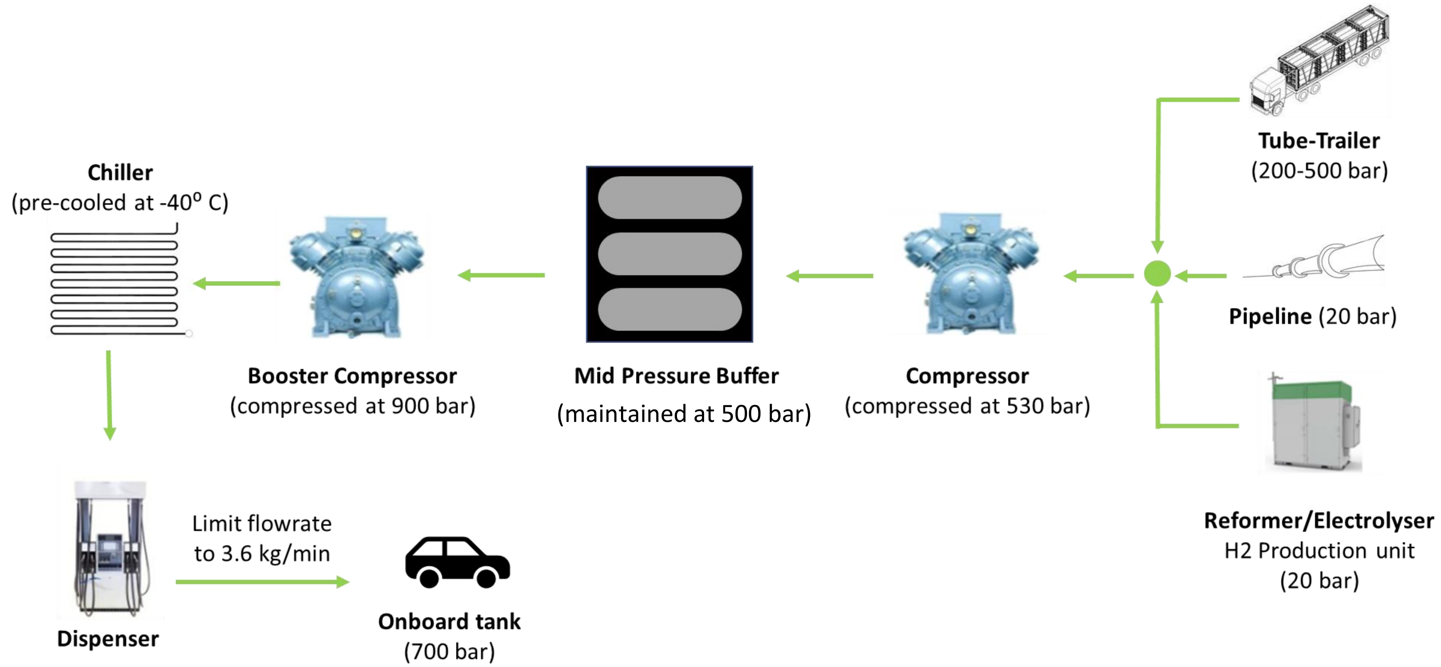
The following elements should be considered to ensure safe operations:

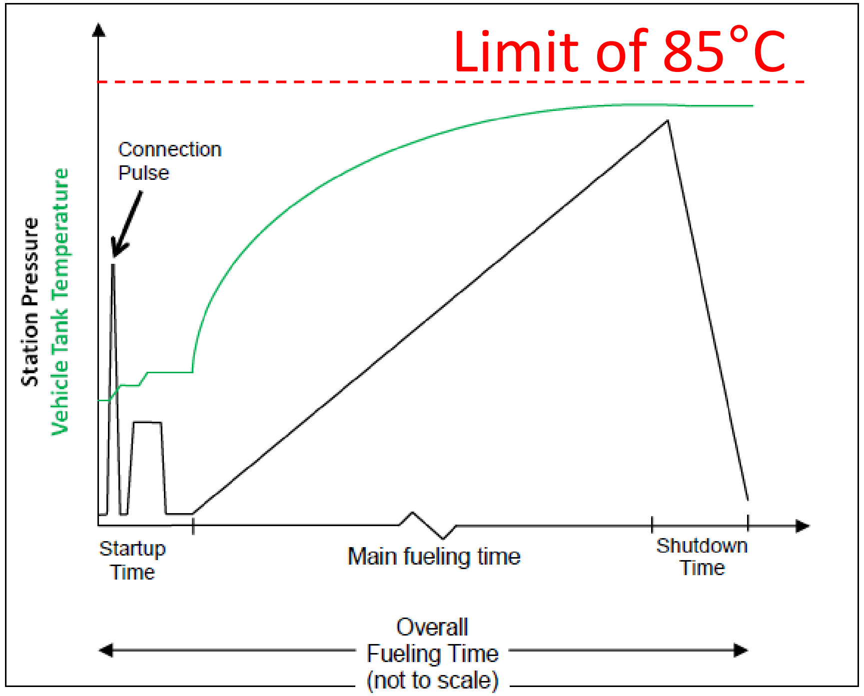
1. **Loss Prevention**: it may be possible to reduce or eliminate risk by "designing out" the hazard.
2. **Ventilation**: providing adequate ventilation will dilute hydrogen air mixtures, minimizing hazards caused by leaks.
3. **Electrical**: providing the correct electrical equipment and instruments will eliminate some potential ignition sources.
4. **Leak Detection**: special techniques are required to reliably detect hydrogen leaks.
5. **Flame Detection**: special techniques are required to reliably detect hydrogen flames.
6. **Storage and Use**: selecting the right kind of storage and the proper location can go a long way towards reducing risk.
7. **Venting**: vent systems are necessary to move hydrogen purged from the system to a safe location.
8. **Instruments and Controls**: safety of the facility can be improved by using interlock systems working in unison with hydrogen and fire detectors.
9. **Construction**: good facility construction is necessary to achieve a safe hydrogen system installation.

Safety strategy, an example:



Refueling protocol:





Three main targets:

- short refueling time: ~ 3 min
- long driving range: 600 – 700 Km
- high safety and reliability

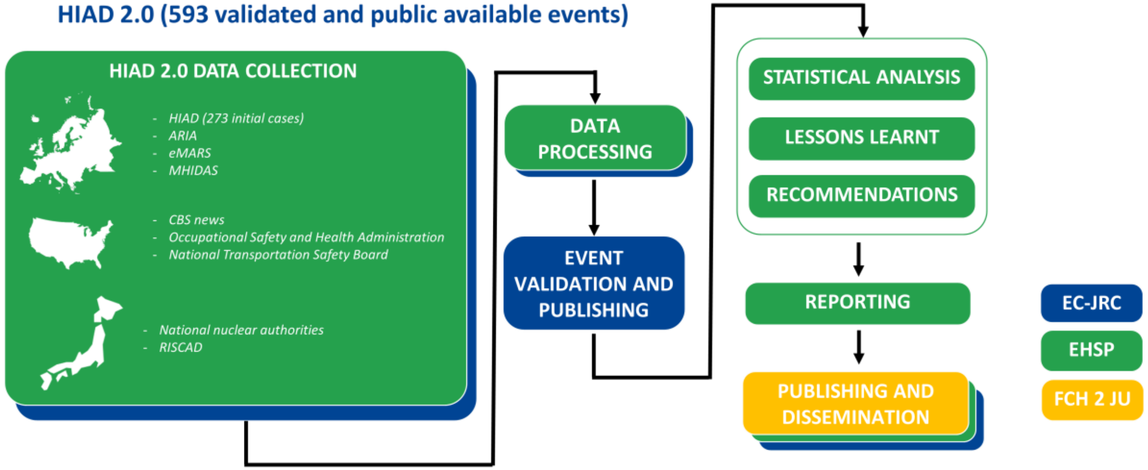
SAE INTERNATIONAL

SURFACE VEHICLE STANDARD	J2601	JUL2014
	Issued 2010-03 Revised 2014-07 Superseding J2601 MAR2010	

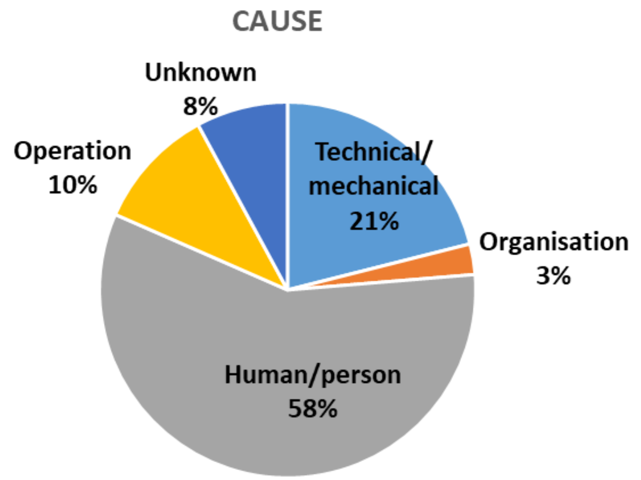
Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles

Lessons learnt from safety-related events

HIAD 2.0 (593 validated and public available events)



Hydrogen transport and distribution & Road vehicle



Main causes (not including near misses)

- Poor maintenance and inspection
- Maintenance procedure not followed
- Need to update communications plans and training program
- Not adequate design or/and material selection
- Not adequate preventing measures
- The transfer requires perfect interoperability