BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

Sept 19 2023

LESSONS LEARNED FROM HYDROGEN ACCIDENTS

(EVENTS REPORTED IN THE IN EAST CONTINENTAL ASIA)

Bin Wang[a], Pietro Moretto[b], Georg Mair[a], Teresa Orellana Pérez[a]

[a] *Federal Institute for Materials Research and Testing, Unter den Eichen 87, 12205 Berlin, Germany*

[b] *Joint Research Centre JRC, European Commission, Westerduinweg 3, Petten 1755 LE, Netherlands*

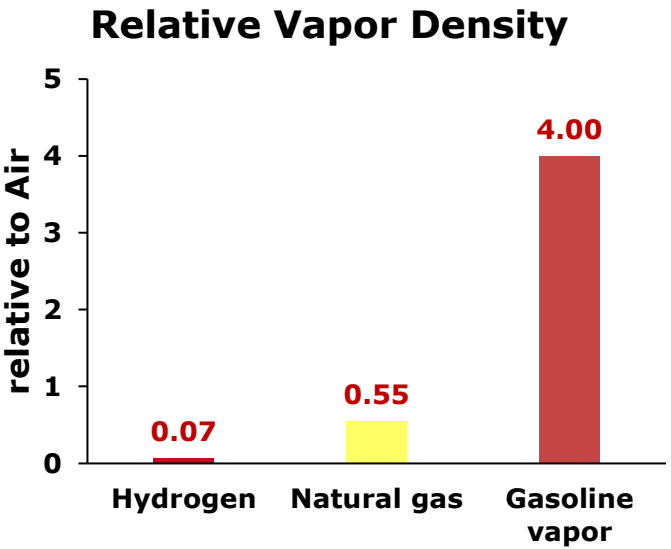
www.bam.de

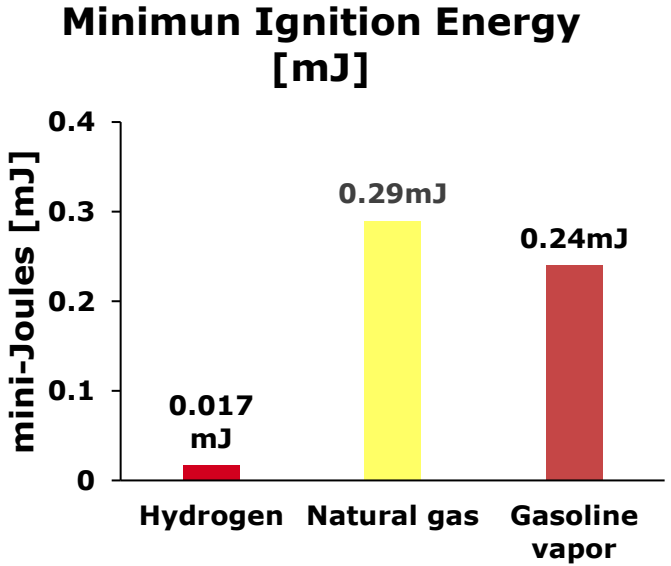
Contents

In collaboration with

- **Risks of using hydrogen as an energy carrier**
- **H2 accidents over the last 20 years in China**
- **Statistical evaluations of the acccidents**
- **Lessons learned**
- **Discussion and questions**

Hazards of using hydrogen as an energy carrier

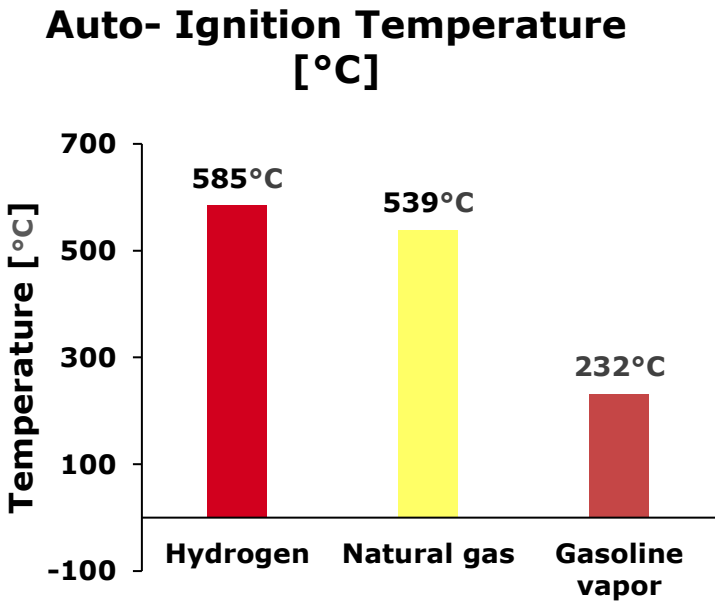




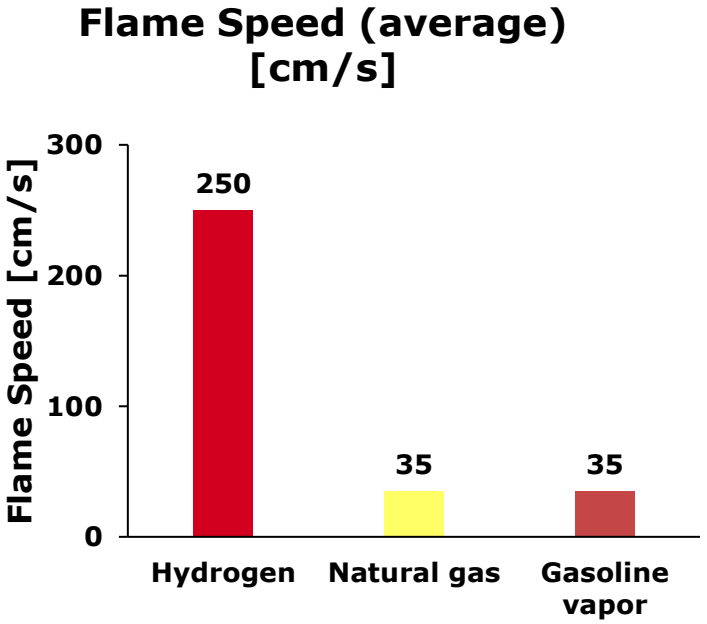
H2 is about 57 times lighter than gasoline vapor and 14 times lighter than air.

H2: very small ignition energy

Hazards of using hydrogen as an energy carrier



Melting point: Zinc 420°C; Aluminum 660°C



Hydrogen flames travel at a very high speed

Hazards of using hydrogen as an energy carrier

Auto-ignition

Electrostatic ignition:
- spark from isolated conductor
- Brush discharges
- Corona discharges

Diffusion ignition: release high pressure H2 gas producing shock waves exceeding several Mach number (T<ignition temperature).

Sudden adiabatic compression: in shock wave formation

Hot surface ignition

H2 accidents over the last 20 years in China

- 2x Metal hose of hydrogen tank ruptured.
- 1x Trailer traffic accidents.
- 2x Cracks in welding areas of hydrogen gas pipe (electrostatic charge).

- 1x Corrosion caused H2 gas pipe rupture (electrostatic sparks).
- 1x A large vibration of the power generator caused by electrical fault, resulting in sealing damage (electrostatic charge).
- 1x Poor design of flange resulting leakage and fire (frictional fire, electrostatic sparks).
- 1x Misconnected electrodes of the hydrogen generator caused leakage and explosion. (10m^3 hydrogen storage tank explosion).
- 1x Hydrogen and oxygen pressure regulator needle valve jammed, gas ignition. (friction generate heat and ignition energy above).

- 1x Laboratory, pressure vessel explosion caused by burning chemical substance.
- 1x Mishandling of h2 pressure vessel in shop (no fire).

H2 accidents over the last 20 years in China

- 1x Explosion in hydrogenation tower (ignition caused by using non-explosion-proof tools).
- 1x Explosion in carbon synthesis plant (5 death, 1 severe injured, 25 injured in different degree, explosion area about 680m^2, 2000k yuan damage).
- 1x Hydrogen leak from a fertilizer plant, (a fire caused by frictional fire).
- 1x Gas pipeline leak, reason unknown (electrostatic charge).
- 1x Hydrogen cylinder explosion caused by fault of safety device in compressor.
- 1x Valve problem, poor design.
- 1x Explosion, reason not published.

These events will be input in the European Hydrogen Incidents Database HIAD, available for download at:
https://minerva.jrc.ec.europa.eu/en/shorturl/capri/hiadpt

H2 accidents involving Hydrogen tranportation

Time: **December 1, 2019**
Location: Middle East China

Main processes

A trailer **containing 300kg of hydrogen** was rear-ended which started a fire.
The hydrogen tank was ruptured due to the impact on the rear of the tank, which caused a fire and quickly ignited.
After about one hour of supervision and disposal, the hydrogen tanker was no longer in danger of explosion.

Casualties: driver injured

The explosion can be prevented by cooling down the temperature using water.

H2 accidents involving hydrogen storage

Time. **July 30, 2020**

Location: South China

Main processes: during hydrogen refuelling up to 7.5MPa, H2 leak due to rupture of the hose. After 5 minutes, the leaking hydrogen started to burn: rupture hose **hits object and causing a spark to ignite the leaked hydrogen gas,** after 13 mins firefighters start spraying water on and around the fire to cool it down, after one hour, the fire stopped.

Casualties: no people injured.

Lessons learned: not using poor quality products

Delayed ignition, quick response needed.
H2 sensor can detect leaks.

H2 accidents involving Hydrogen storage

Time **August 4, 2021**

Location: Northern China

Main processes:

Filling hose ruptured due to poor design and bursted into flame, causing the tyres to burn and produce thick, black smoke. Ignition source is not clear but the fire was effectively controlled.

Cause: Filling hose ruptures (poor design)

Casualties: none

H2 accidents involving hydrogen production

Time: **April 23, 2011**

Location: Sichuan, Western China

The methanation furnace in the gas workshop of a Biochemical company. (corrosion crack at welding area).

Cause: The welded joints of the outlet pipes were operating for a long time in the high temperature hydrogen containing gases. The defect was initiated and quickly developed. Hydrogen leakage occurred, and without safety measures, plugging and repair was carried out against the rules, therefore generating sparks and causing the explosion of the gas pipes.

Casualties: 4 people died, 2 people were injured.

Delayed ignition.
How to stop ignition safely?

H2 accidents involving hydrogen application

Time: **Dec 18, 2015**

Location: laboratory of the Chemistry Department of an University in Beijing

Main processes: the hazardous chemical substance tert-Butyllithium stored in the incident laboratory started burning, causing the hydrogen pressure cylinder stored in the laboratory to explode in the fire.

Cause: pressure vessel explosion caused by burning of chemical substance.

Casualties: instant death of a post-doc.

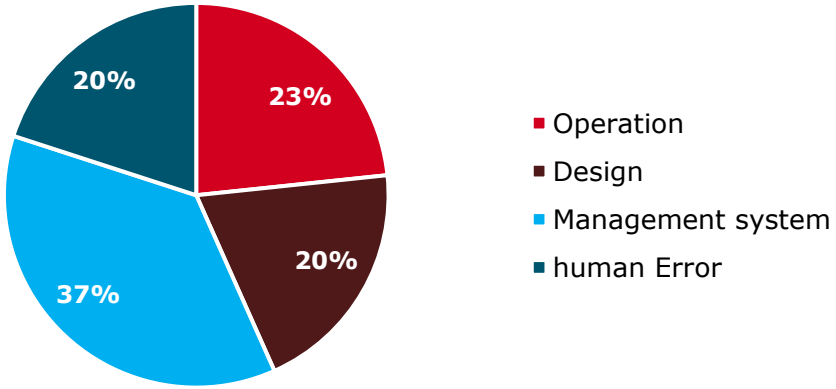
H2 accidents over the last 20 years in China

	Major Hazard Incident Database Service of the Health and Safety Executive (UK):	H2 accidents over the last 20 years in China
Incidents of hydrogen gas release	81	19
Delayed ignition	5%	40%
Immediately ignition	95%	60%
Ignition source cannot be identified	86,3%	10,5%

Delayed ignition: time can be used to react.
Immediately ignition: to prevent electrostatic charges.

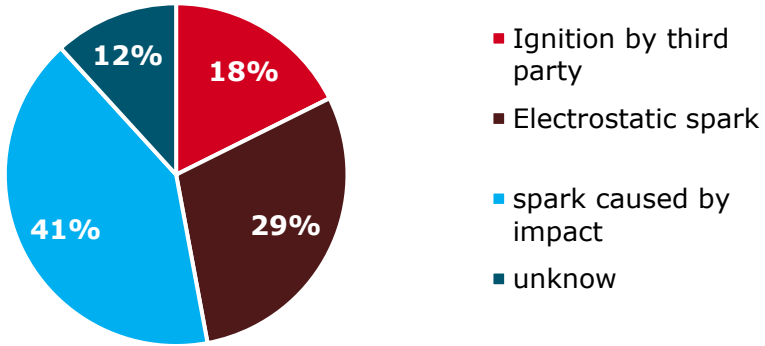
Statistical evaluations of the accidents

Root cause of accidents



Safety Management System plays a major role.

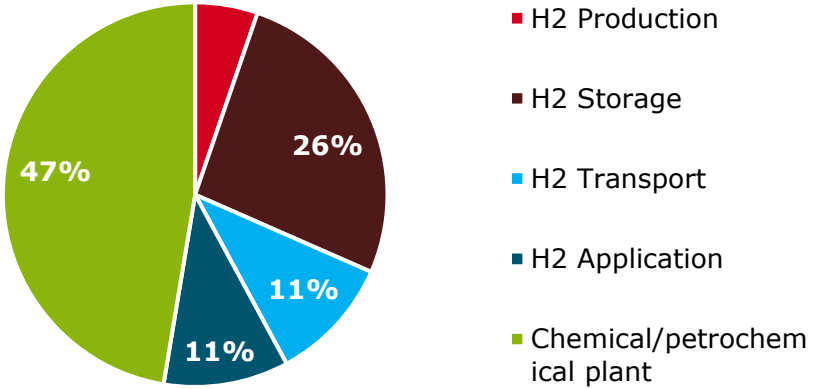
Cause of Ignition



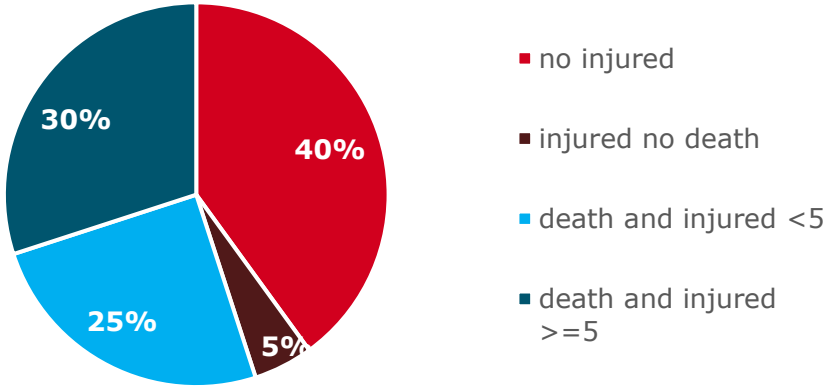
Ignitions are mainly caused by electrostatic charges.

Statistical evaluations of the accidents

Sectors of accidents



Casualties



Lessons learned and recommedations

- Using hydrogen safety sensors, alarm and warning system to detect the leak.
- Using automatic control of the shutdown systems by leak or fire.
- Safety measures to prevent electrostatic charges.
- To optimize prevention/mitigation measures and design Research on the effect of release-to-ignition times and to ignition sources, possibly by specific modelling works and experiments mimicking selected incidents, is still necessary.
- Quick response of firefighting and choice of the optimal firefighting strategy adapted to the specific situation. For example, cooling down the affected components (but knowing when and how to do so).

Lessons learned and recommedations

- Monitor critical process parameters (pressure, temperature and hydrogen concentration).
- Fail safe design concept is needed
- Operative aspects: inspections/maintenance. Early identification of corrosion, fatigue, overpressure, thermal stress.
- Quality control along the whole supply chains: avoid products of poor quality.
- Continuous improve the safety management, adopting a management of change approach.

Discussion and questions

- Many incidents were triggered by a complex combination of causes: materials and components failures, and also design and operative procedures shortcomings and human errors.

- How can we use AI, Digital Twin, QI Digital or other methods to prevent the accidents?

- Do we need to alternative methods for hydrogen storage?

Danke für Ihre/Eure Aufmerksamkeit

Bin Wang

+49 30 8104-3176

Bin.Wang@bam.de

www.bam.de