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Hydrogen-Explosion Risk Reduction by Area Classification

Shiv Jadeja
HSE Director (Fire Protection)
FLUOR

Nishin Haris
HSE Engineer IV (Process Safety)
FLUOR

FLUOR OVERVIEW

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- Designs and builds well-executed, capital-efficient projects for clients around the world
- More than 110-year heritage providing solutions for clients through our Energy Solutions, Urban Solutions and Mission Solutions business groups
- Global execution platform serving clients in over 60 countries
- #303 on the 2023 FORTUNE® 500 list
- 40,000 employees executing projects globally

OUR PURPOSE

WE BUILD

A BETTER WORLD

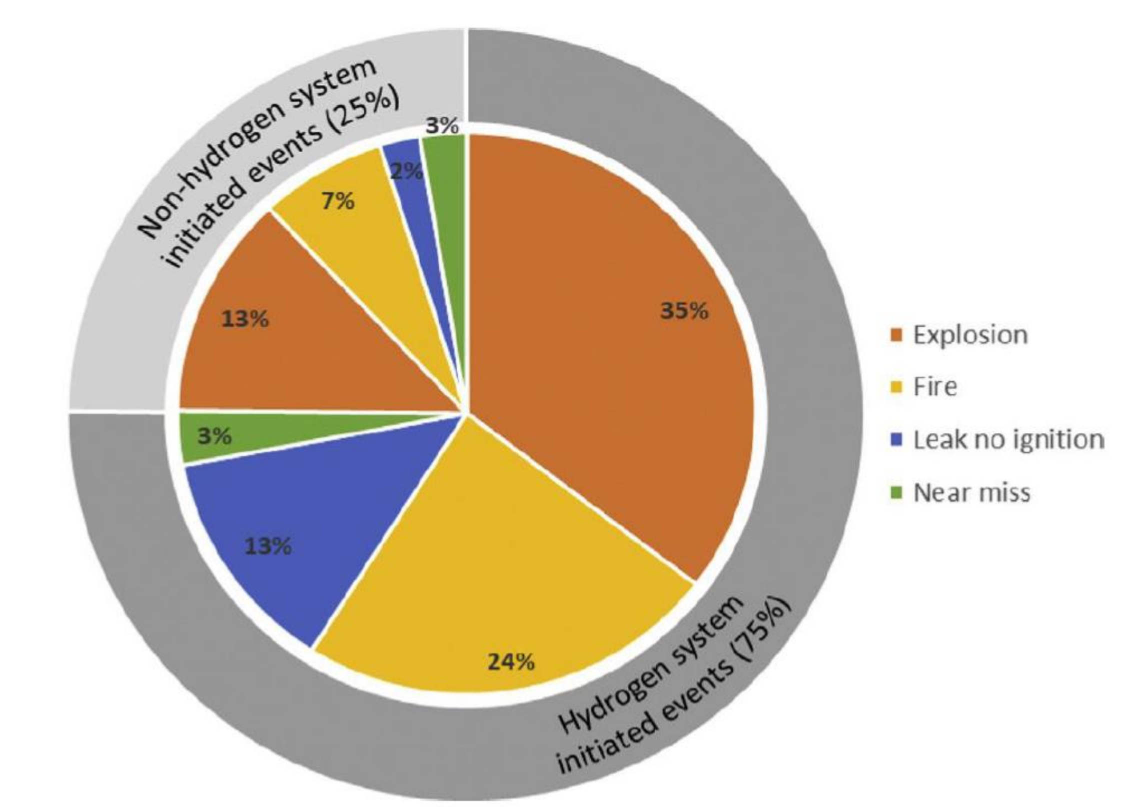
We are committed to reducing our Scope 1 and Scope 2 greenhouse gas (GHG) emissions to net zero by the end of 2023.

Topics

- Introduction/Previous Accidents
- Hydrogen Properties and Challenges
- What is Hazardous Area Classification (HAC)
- Standards/Guidance on HAC
- Case Study
- Conclusions

Introduction

- Hydrogen technologies : Key role in energy transition projects
- Hydrogen projects to be executed safely and cost-effectively
- H2 Fire/Explosion risk in confined spaces key concern



Previous Accidents : H2 Explosions

1 Herøya, Norway, 1985

- 10-20kg H2 releases and explosion in ammonia production plant.
- Two death and third person severely injured.
- Roof lifted 1m high, side walls blown out at 60 m, windows shattered.

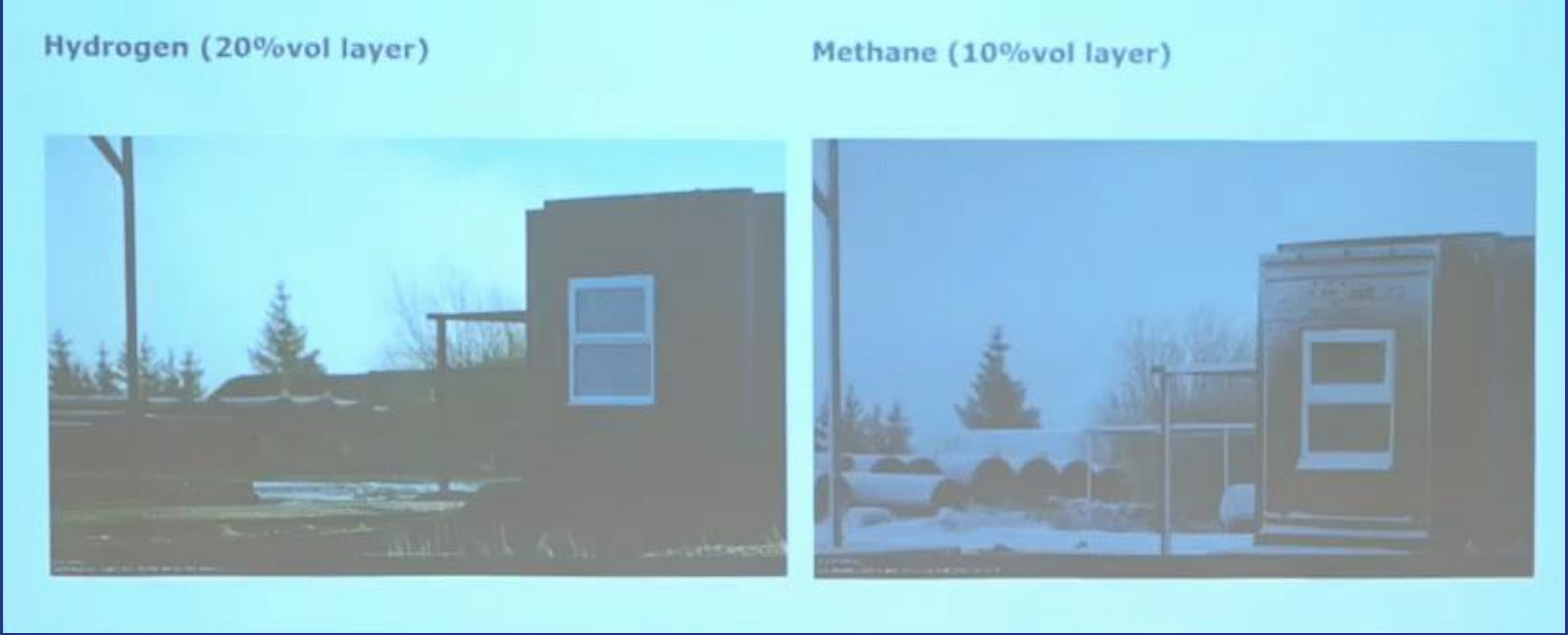
2 Ohio, USA, 2007

- Explosion American Electric Power plant.
- One fatality, injuries to 10 other people.
- Significant damage to several buildings

3 Kjørbo, Norway, 2019

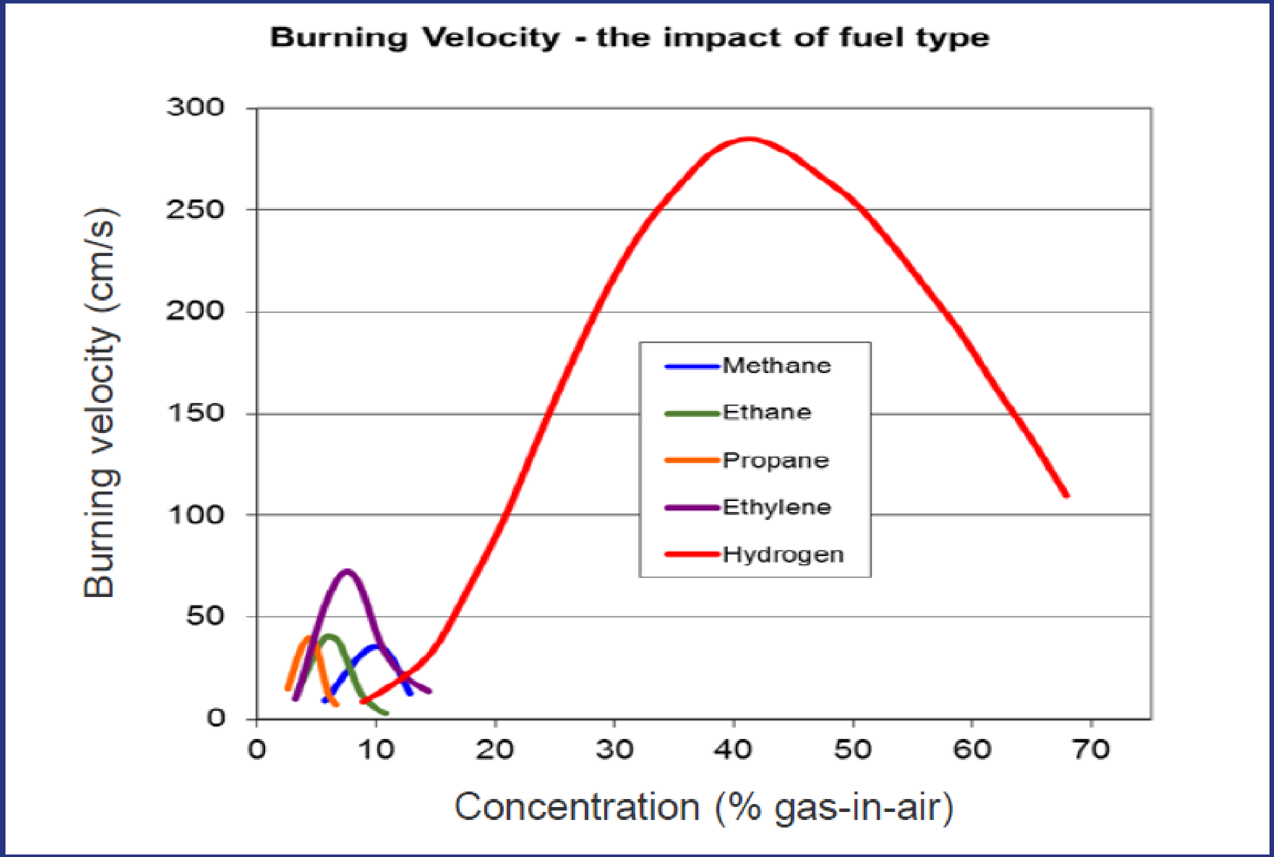
- Explosion hydrogen fueling station
- No fatality, two major injuries.
- Tiggered airbags in nearby cars
- Safety zone of 500 meters

CH4 & H2 Explosion Comparison (test result from DNV)



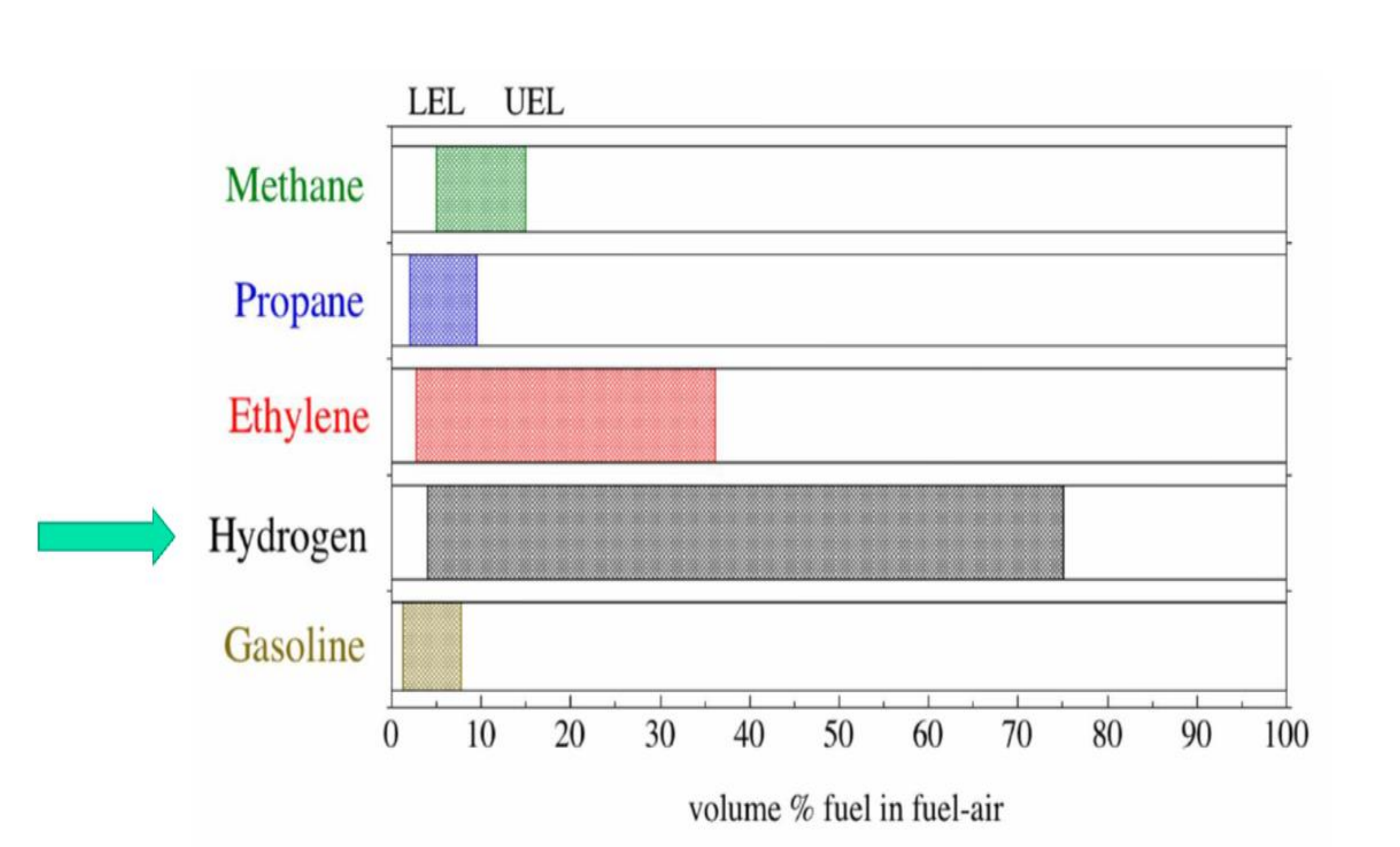
Hydrogen Properties : Burning Velocity

- H2 has much higher burning velocity than other Hydrocarbons.
- Higher the burning velocity, the more severe the explosion



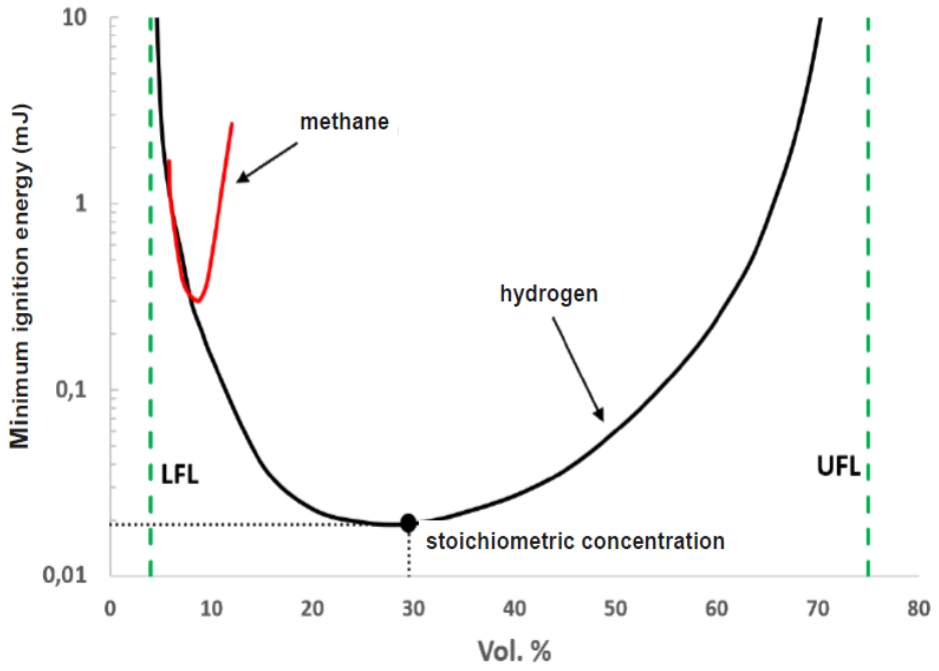
Hydrogen Properties : LEL/UEL

- LEL : Lower Explosive Limit
- UEL : Upper Explosive Limit



Hydrogen Properties : Minimum Ignition Energy

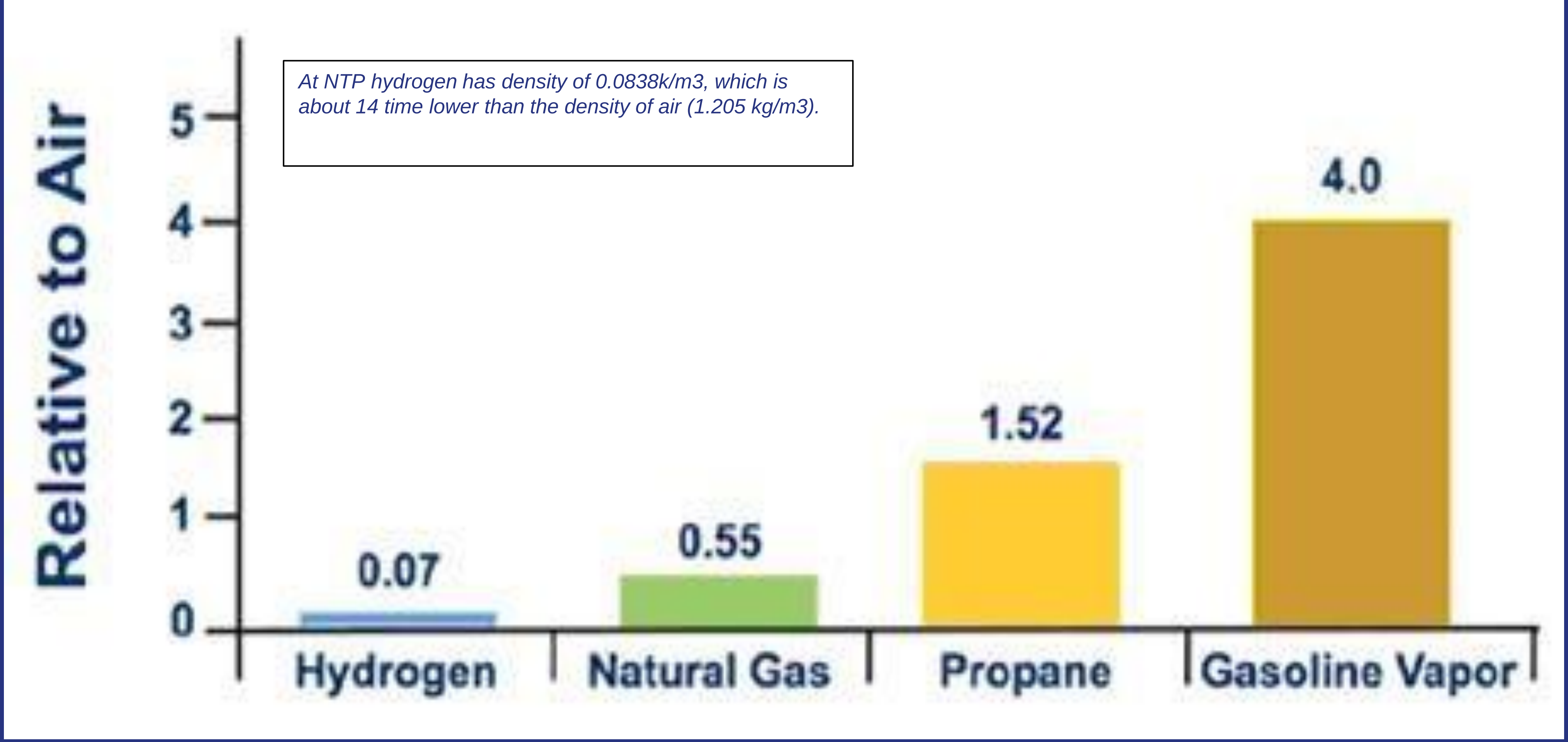
Minimum energy of an electrical spark able to start combustion



Minimum ignition energy
Methane: 0.28 mJ
Hydrogen: 0.017 mJ

GROUP	COMPOUND	MESG(mm)	MIC ratio
IIC	Acetylene, hydrogen , or flammable gases or combustible liquid produced vapour mixed with air that may explode or burn	≤0.5	≤0.45
IIB	Acetaldehyde, ethylene, , or flammable gases or combustible liquid produced vapour mixed with air that may explode or burn	>0.5 ≤0.9	>0.45 ≤0.8
IIA	Acetone, ammonia, ethyl alcohol, gasoline, methane, propane, or flammable gases or combustible liquid produced vapour mixed with air that may explode or burn	>0.9	>0.8

Hydrogen Properties : Density



Hydrogen Properties : Auto Ignition Temperature

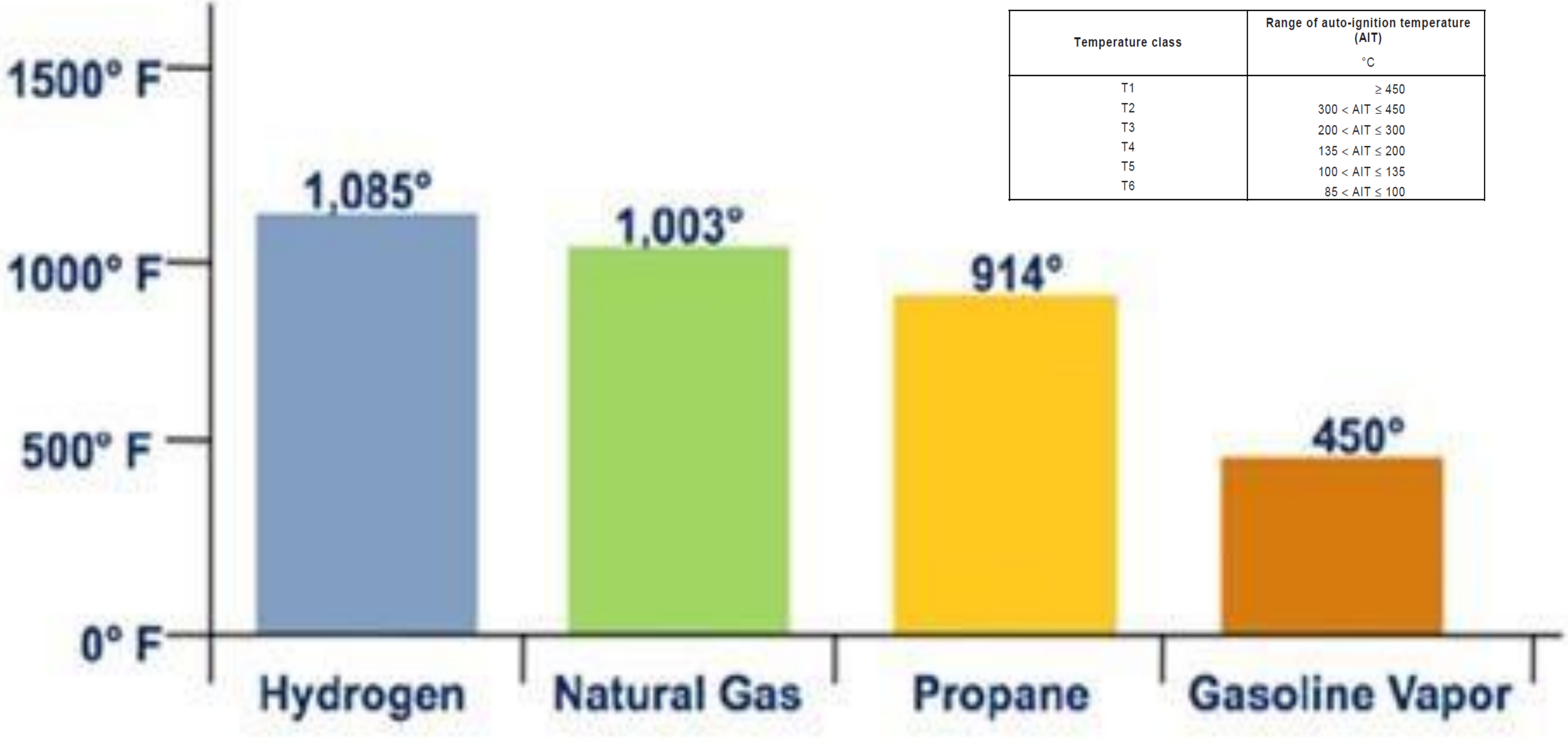
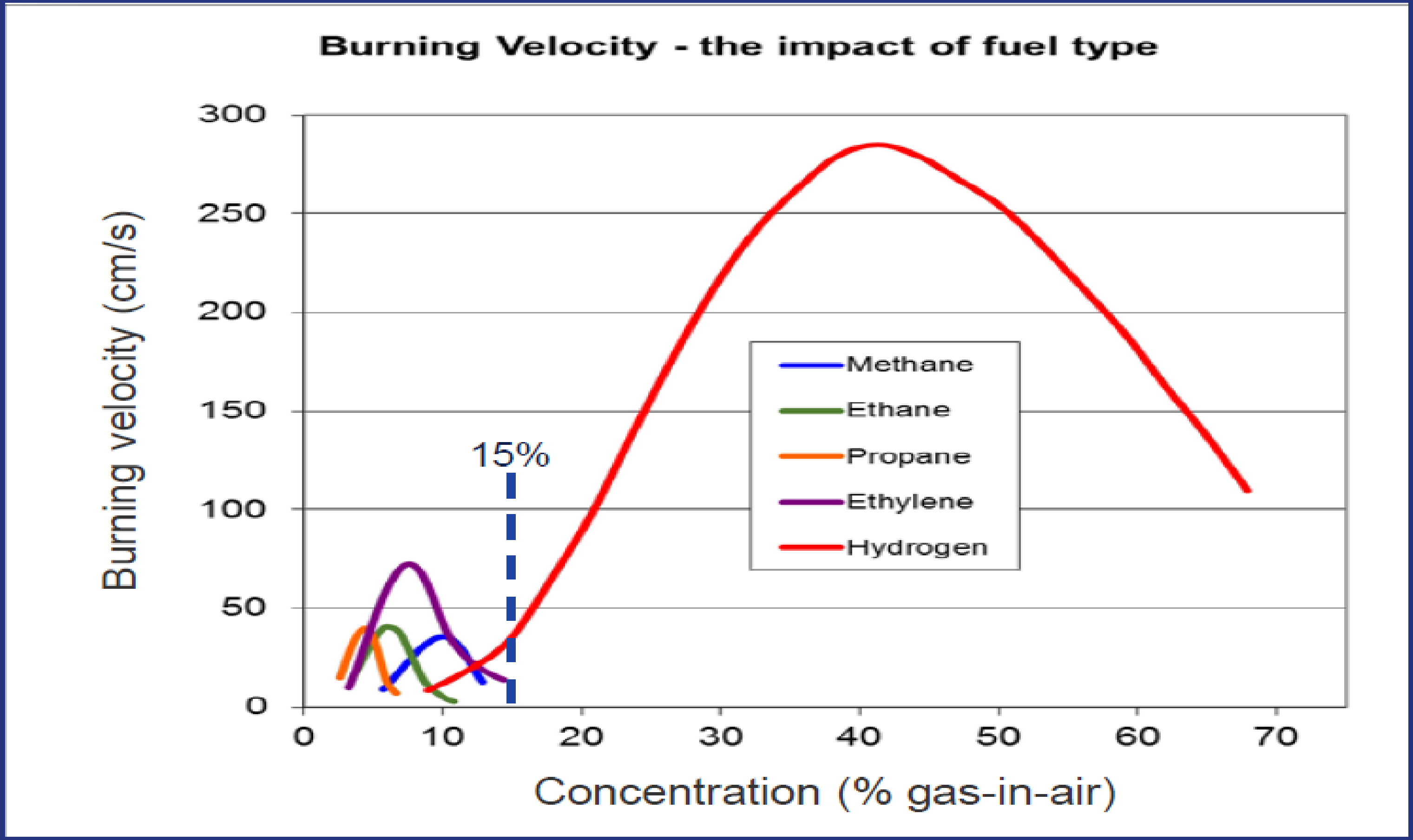


Table 1 – Classification of temperature class and range of auto-ignition temperatures

Temperature class	Range of auto-ignition temperature (AIT) °C
T1	≥ 450
T2	300 < AIT ≤ 450
T3	200 < AIT ≤ 300
T4	135 < AIT ≤ 200
T5	100 < AIT ≤ 135
T6	85 < AIT ≤ 100

Managing H2 Explosion Risk



Remember this ?

If the H2 concentration is kept below ~15% (by Vol) then no worse than Natural Gas

Hydrogen MAQ: NFPA 2 Recommendation

Pin Header

Table 6.4.1.1.1 Maximum Allowable Quantity of Hydrogen per Control Area (Quantity Thresholds Requiring Special Provisions)

Material	Unsprinklered Areas		Sprinklered Areas	
	No Gas Cabinet, Gas Room, or Exhausted Enclosure	Gas Cabinet, Gas Room, or Exhausted Enclosure	No Gas Cabinet, Gas Room, or Exhausted Enclosure	Gas Cabinet, Gas Room, or Exhausted Enclosure
LH_2	0 gal (0 L)	45 gal (170 L) *	45 gal (170 L)	45 gal (170 L)
GH_2	1000 scf (26.3 Nm^3)	2000 scf (52.6 Nm^3)	2000 scf (52.6 Nm^3)	4000 scf (105.1 Nm^3)

For SI units: 1 ft = 304.8 mm; 1 scf = 0.02832 Nm^3.

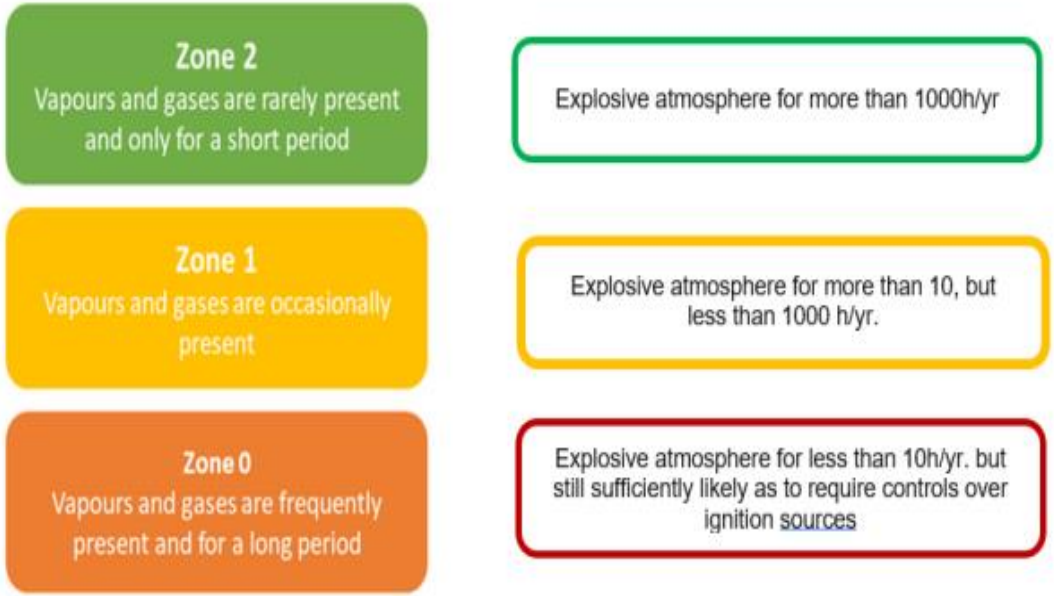
Note: None allowed in unsprinklered buildings unless stored or used in gas rooms or in approved gas cabinets or exhausted enclosures, as specified in this code, and pressure-relief devices for stationary or portable containers vented directly outdoors or to an exhaust hood.

*A gas cabinet or exhausted enclosure is required (*see also* ***6.4.1.1.2***).

Indoors or in enclosures if the static volume of GH_2 or LH_2 (STP) contained in a process or transported in piping systems in the enclosure is equal to or greater than 0.004 (0.4 percent) times the enclosure volume and the piping or container or equipment is disconnected during normal operations while at least some hydrogen remains pressurized.

What is Hazardous Area Classification (HAC)

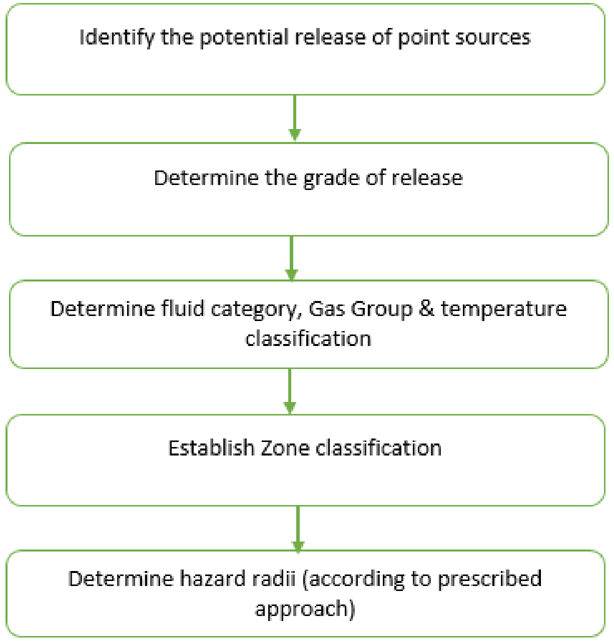
- Analysing and classifying the environment (where explosive gas atmospheres may occur)
- Plant area in different zones
- Decide if electrical and other equipment needs special protective features in order to prevent it causing a fire or explosion



HAC Methodology

Identify sources of release of flammable gas or vapour

- ❑ May arise from constant activities;
- ❑ from time to time in normal operation;
- ❑ or as the result of some unplanned event.



Note : Catastrophic failures not considered for area classification

Code & Standard

UK/Europe	America/Canda	Asia
BS EN 60079-10:2021 EI 15 *IEC 60079-10-1:2020*	NFPA 497 API-RP-505 NFPA 2: Hydrogen Technology Code CAN/BNQ 1784-000	Indian: OISD 113, IS-5571

Table 1 : List of Area Classification Related Code and Standard

Case Study: Facility Description & Challenges

- Multiple Fuel Testing Facility
- Existing Occupied Building
- Regulatory Challenges
- Space Constraints
- Existing Equipment Capacity
- Fast Track Project

Case Study: HAC Input Used

- Area Classification : BS EN 60079-10-1
- Release source : *Valve, Flanges,*
- H2 feed line : *7.5barg/50oC*
- Selected Hole size : *0.564mm ; S=0.25mm2*
- Flow Rate : *9.5E-5kg/sec (estimated using DNV Phast)*

Table B.1 – Suggested hole cross sections for secondary grade of releases

Type of item	Item	Leak Considerations: Typical values for the conditions at which the release opening will not expand	Typical values for the conditions at which the release opening may expand, e.g. erosion	Typical values for the conditions at which the release opening may expand up to a severe failure, e.g. blow out
		S (mm^2)	S (mm^2)	S (mm^2)
Sealing elements on fixed parts	Flanges with compressed fibre gasket or similar	≥ 0,025 up to 0,25	> 0,25 up to 2,5	(sector between two bolts) × (gasket thickness) usually ≥ 1 mm
	Flanges with spiral wound gasket or similar	0,025	0,25	(sector between two bolts) × (gasket thickness) usually ≥ 0,5 mm
	Ring type joint connections	0,1	0,25	0,5
	Small bore connections up to 50 mm[a]	≥ 0,025 up to 0,1	> 0,1 up to 0,25	1,0
Sealing elements on moving parts at low speed	Valve stem packings	0,25	2,5	To be defined according to Equipment Manufacturer's Data but not less than 2,5 mm^2 [d]
	Pressure relief valves[b]	0,1 × (orifice section)	NA	NA
Sealing elements on moving parts at high speed	Pumps and compressors[c]	NA	≥ 1 up to 5	To be defined according to Equipment Manufacturer's Data and/or Process Unit Configuration but not less than 5 mm^2 [d and e]

[a] Hole cross sections suggested for ring joints, threaded connections, compression joints (e.g. metallic compression fittings) and rapid joints on small bore piping.

[b] This item does not refer to full opening of the valve but to various leaks due to malfunction of the valve components. Specific applications could require a hole cross section bigger than suggested.

[c] Reciprocating Compressors – The frame of compressor and the cylinders are usually not items that leak but the piston rod packings and various pipe connections in the process system.

[d] Equipment Manufacturer's Data – Cooperation with equipment's manufacturer is required to assess the effects in case of an expected failure (e.g. the availability of a drawing with details relevant to sealing devices).

[e] Process Unit Configuration – In certain circumstances (e.g. a preliminary study), an operational analysis to define the maximum accepted release rate of flammable substance may compensate lack of equipment manufacturer's data.

NOTE Other typical values or guidance on erosion and failure conditions may also be found in national or industry codes relevant to specific applications.

Case Study: Ventilation Study Result

a) High dilution

The concentration near the source of release reduces quickly and there will be virtually no persistence after the release has stopped.

b) Medium dilution

The concentration is controlled resulting in a stable zone boundary, whilst the release is in progress and the explosive gas atmosphere does not persist unduly after the release has stopped.

c) Low dilution

There is significant concentration whilst release is in progress and/or significant persistence of an explosive gas atmosphere after the release has stopped.

Note:
If background concentration exceeds 25 % of the LFL the degree of dilution is considered as low.

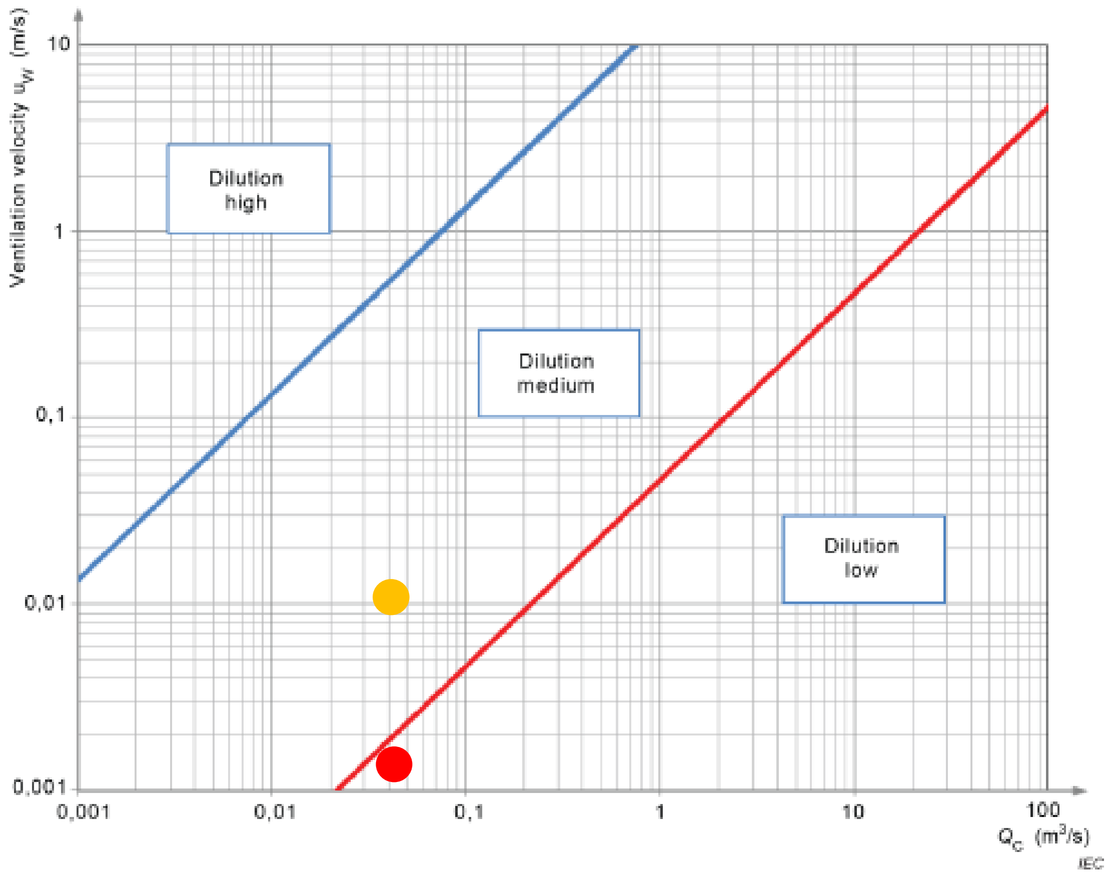


Figure C.1 – Chart for assessing the degree of dilution

Case Study : Zone Classification

- 2 ACH : Zone 1, IIC, T1
- 6 ACH : Zone 2, IIC, T1

Table D.1 – Zones for grade of release and effectiveness of ventilation

Grade of release	Effectiveness of Ventilation						
	High Dilution			Medium Dilution			Low Dilution
	Availability of ventilation						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	Non-hazardous (Zone 0 NE)[a]	Zone 2 (Zone 0 NE)[a]	Zone 1 (Zone 0 NE)[a]	Zone 0	Zone 0 + Zone 2[c]	Zone 0 + Zone 1	Zone 0
Primary	Non-hazardous (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 2 (Zone 1 NE)[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[d]
Secondary[b]	Non-hazardous (Zone 2 NE)[a]	Non-hazardous (Zone 2 NE)[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even Zone 0[d]

[a] Zone 0 NE, 1 NE or 2 NE indicates a theoretical zone which would be of negligible extent under normal conditions.

[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[c] Zone 1 is not needed here. I.e. small Zone 0 is in the area where the release is not controlled by the ventilation and larger Zone 2 for when ventilation fails.

[d] Will be Zone 0 if the ventilation is so weak and the release is such that in practice an explosive gas atmosphere exists virtually continuously (i.e. approaching a 'no ventilation' condition).

'+' signifies 'surrounded by'.

Availability of ventilation in naturally ventilated enclosed spaces is commonly not considered as good.

Case Study :Gas Detection

L.3 Location of Gas Detectors to Effectively Detect Hydrogen.

The following should be considered to effectively locate gas detectors where they are most likely to detect an unintended hydrogen release:

(1) Hydrogen buoyancy, which dictates that sensors should be placed above any potential release point.

(2) A gas detector mounting on the ceiling should be avoided because of elevated temperatures at the ceiling. Gas detectors should be mounted a foot or more below the ceiling—possibly using the wall.

(3) The gas detector should be mounted facing the potential release point. However, considerations should be given to the effect ventilation would have on air flow and how this alteration of air flow might impact the direction or orientation of the release point.

(4) The gas detector should be effectively downwind of any potential air flow.

(5) Hydrogen gas detectors should not be located in any structural entrapments.

(6) Hydrogen gas detectors can also be mounted on a wall close to but above the hydrogen dispensing system.

Conclusion

- H2 is low-carbon energy source for industrial and transportation uses.
- H2 is highly flammable/explosive and accidents have happened industry.
- Area classification, followed by adequate ventilation, rapid gas detection and isolation is key in explosion safe design.

QUESTIONS?
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