MultHyFuel

MultHyFuel Final Event Introduction

Dinko Đurđević
Hydrogen Europe

17th June 2025

Clean Hydrogen Partnership

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research

Content

Time	Title	Speaker
14.00 - 14.10	**About MultHyFuel**	**Hydrogen Europe**
14.10 - 14.20	Permitting Requirements in Europe	Hydrogen Europe
14.20 - 14.25	MultHyFuel Final Deliverable D3.7/8: Developing Good Practice Guidelines in Project MultHyFuel: Structure and Terms of Reference/ Caveats	HSE SD (Ju Lynne Saw)
14.25 - 14.40 14.40 - 15.10 15.10 - 15.25	Risk Assessment Approach: Methodology and Likelihoods Consequence Analysis •Experimental findings Hazardous Area Classification Example	INERIS (Sylvaine Pique) HSE SD (recording of Louise O'Sullivan) ITM Power (David Torrado)
15.25 - 15.40 15.40 - 15.50	6.1 Recommendations and technical suggestions for further research to inform the development and/or update of Codes and Standards: •Dispenser design •Hazardous Area Classification 6.2 Technical suggestions for further research and harmonisation of good practice	ITM Power (Nick Hart) ITM Power (David Torrado) INERIS (Sylvaine Pique)
15.50 - 16.00	Closing and Post project activities	Hydrogen Europe

Background and context

With increasing demand for FCEV, Hydrogen Refueling Stations are required to be upscaled and co-located alonsige conventional fuels in commercial and residential areas.

The problem:

- In some countries, specific regulations for HRS don't exist
- Co-location of hydrogen with conventional fuels is not seen in most safety regulations
- Different approaches are taken by different countries

HyLAW

"(…) lack of guidelines and instructions for local authorities can cause **delays** and **extra costs** and may lead to **divergent interpretations** from case-to-case, further complicating the obligations of HRS operators."

2018, https://www.hylaw.eu/

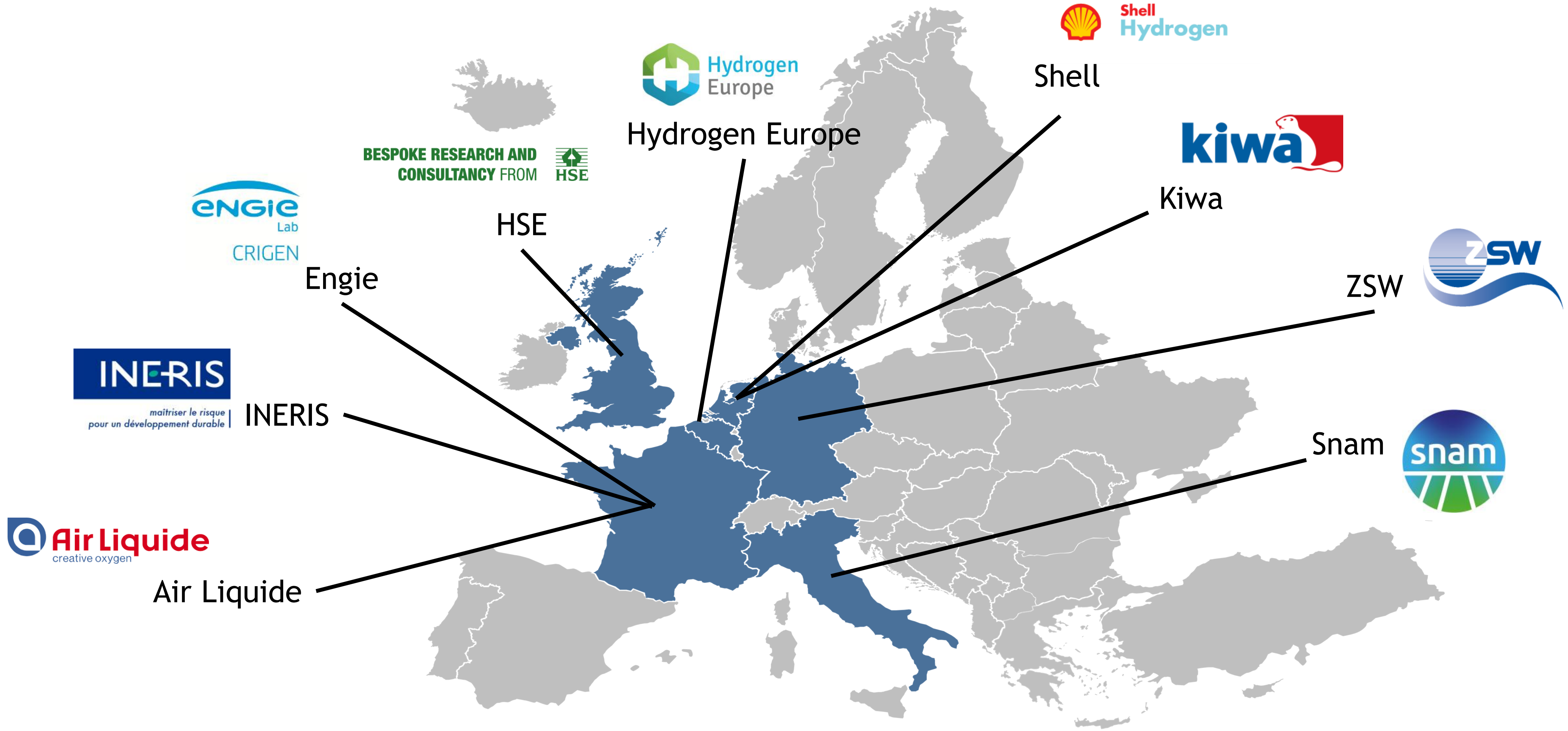
Goals

Goal

Defining **commonly applicable, effective, and evidence-based guidelines** to facilitate the construction of HRS in multi-fuel refuelling stations.

- Identification of relevant gaps in the current legal and administrative framework;
- Acquisition of experimental data from engineering research on hydrogen leaks, their effects and the effects of mitigation measures;
- Actively engage a community of stakeholders in the overall process, from gap identification to review and validation of the solutions proposed, to facilitate evidence-based policy-making;
- Successfully disseminate the project's results.

Consortium



Hydrogen Europe
Hydrogen Europe
Shell Hydrogen
Shell
kiwa
Kiwa
ZSW
ZSW
snam
Snam
BESPOKE RESEARCH AND CONSULTANCY FROM HSE
HSE
engie Lab CRIGEN
Engie
INERIS
maitriser le risque pour un développement durable
INERIS
Air Liquide creative oxygen
Air Liquide

WP structure

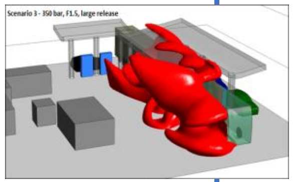
WP6 – Project management

WP1 - Detailed investigation of current status

- T1.1 Definition of scope for regulatory analysis (Cross-country research framework)
- T1.2 Research into permitting requirements and public guidance on required risk assessments
- T1.3 Comparative assessment and gap analysis

WP2 - Practical research to address gaps in current understanding

- T2.1 Leakage characterisation of H2 dispensers
  - Task 2.1.1 Leakage characteristics
  - Task 2.1.2 Dispersion characteristics
  - Task 2.1.3 Ignition probabilities
  - Task 2.1.4 Efficiency of safety barrier
- T2.2 Fire and explosion hazards
  - Task 2.2.1: Defining a zoning threshold
  - Task 2.2.2 Domino effect arising from faults on hydrogen dispensers
  - Task 2.2.3 Vulnerability of hydrogen dispensers to incidents involving other fuel dispensers



WP3 - Generate best practice guidance

- T3.1 State of the art of technology
- T3.2 State of the art on risk assessment methodologies
- T3.3 Preliminary risk analysis
- T3.4 Detailed risk assessment
- T3.5 Identification of critical scenarios
- T3.6 Risk assessment review of critical scenarios & hazardous areas
- T3.7 Best practice guidelines redaction

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	Extreme	Extreme
Possible	Medium	Medium	High	High	Extreme
Unlikely	Low	Medium	Medium	High	High
Rare	Low	Low	Medium	High	High

WP4 – Engagement

- T4.1 Establishment of the Network
- T4.2 Inception phase
- T4.3 Workshop on state of the art and case study models
- T4.4 Workshop on refined case study models and WP2 methodology
- T4.5 Workshop on results of WP2 and WP3
- T4.6 Workshop on development of best practice guidance
- T4.7 Meeting on adoption of best practice guidance (WP3)

WP5 - Dissemination, Communication and exploitation

Clean Hydrogen Partnership

Project duration: 1/2021 - 9/2024

H2 MultHyFuel

Website

Launched July 2021

Includes:

- Summary of project
- Public deliverables
- Slides / recordings from launch event & workshops
- News from project
- Communication, dissemination and exploitation plan

Contact email: info@multhyfuel.eu

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Permitting requirements and methodologies across Europe

Dinko Đurđević
Hydrogen Europe

17th June 2025

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Safety and Permitting for Hydrogen at Multifuel Retail

MultHyFuel

"(…) lack of guidelines and instructions for local authorities can cause **delays**, **extra costs** and **divergent interpretations** from case-to-case, further complicating the obligations of HRS operators."

2018, https://www.hylaw.eu/

Definition of **commonly applicable, effective, and evidence-based guidelines** to facilitate the construction of HRS in multi-fuel refuelling stations through

- Identification of relevant gaps in the current legal and administrative framework;
- Acquisition of experimental data from engineering research;
- Active engagement with a community of stakeholders in the overall process.

Hydrogen Europe · Air Liquide creative oxygen · Bespoke Research and Consultancy from HSE · INERIS maîtriser le risque pour un développement durable · ENGIE Lab CRIGEN · ITM POWER Energy Storage | Clean Fuel · kiwa · snam · Shell Hydrogen · ZSW

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WP1 – Permitting requirements in the EU

Preliminary extensive diagnosis of the existing rules, standards and best practices in the domain.

Goal

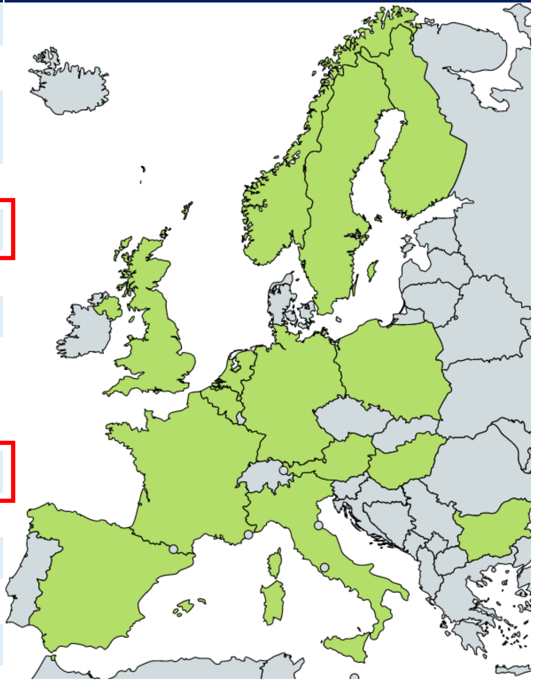
- Collect specific information on requirements, rules, conditions, standards applicable at national level in 14 European countries (Network of National Experts);
- Comparative assessment and gap analysis.

Scope of research

- Existing permitting requirements for HRS;
- Risk Assessment regulations/methodologies;
- Safety or separation distances;
- Intervals and content of equipment maintenance.

Network of National Experts

COUNTRY	ORGANIZATION	EU COVERAGE & REPRESENTATIVENESS
AT	Austrian Energy Agency	
BE	WaterstofNet vzw	
BG	Bulgarian Hydrogen, Fuel Cell and Energy Storage Association	
FI	VTT Technical Research Centre of Finland LTD	
FR	France Hydrogéne	
DE	ZSW	
HU	Hungarian Hydrogen & Fuel Cell Association	
IT	Italian National Agency for new technologies, energy and sustainable economic development and H2 Italy	
NL	NEN	
PL	NEXUS Consultants	
ES	Aragon Hydrogen Foundation	
SE	Hydrogen Sweden	
UK	ITM Power	
NO	Greenstat	



Existing permitting requirements for HRS

Guidance

- 4 countries with HRS specific regulation and HRS deployed
- 7 countries without HRS specific regulation but HRS deployed
- 3 countries without any HRS deployed

Process duration

- 5-6 months on average
- There are regulated time limits for granting permit after submission (DE, AT), but even in those cases they can be surpassed

General takeaways

- Process is not standardised in most countries (authorities need to be involved from very beginning)
- Most rules applied refer to CNG rules or hydrogen used in industrial context
- Overly cautious measures are often put in place
- Safety distances are very different among countries

Existing permitting requirements for HRS

Different criteria

France		Germany		UK		Finland	
Distribute < 2kg/day Storage < 100 kg	No formality, only build permit	**Storage < 3 tonnes**	Ordinance of Industrial Safety and Health	**Storage < 2 tonnes**	General planning building permission	**Storage < 2 tonnes**	Only notification to the regional rescue deparment needed
Distribute > 2kg/day Storage < 100 kg	Heading n. 1416	**Storage > 3 tonnes**	Simplified Federal Immission Control Act	**Storage > 2 tonnes**	Planning (Hazardous Substances) Regulations	**Storage > 2 tonnes**	Permitting required under the scope of the Finnish Safety and Chemicals Agency
Distribute > 2kg/day Storage > 100 kg	Headings n. 1416 and n. 4715	**Storage > 30 tonnes**	Formal permit procedure Federal Immission Control Act	**Storage > 5 tonnes**	COMAH Regulation		
Distribute > 2kg/day Storage > 1 tonne	Heading n.1416 and authorized under n.4715						

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Authorities involved and overall process

Netherlands

Authorities in charge

- Municipality issues the permit but gets advice from other entities (Regional safety and environmental agencies)

Existing guidelines/regulation to follow

- There is an online guidelines (in Dutch and English describing the process
- PGS 35 is the main file used describing safety requirements

France

Authorities in charge

- Mayor of the city (one level higher than local level and one level below regional level). Relies on other entities (regional authorities for the environment and safety)
- Process depends on the maximum flow rate and storage of hydrogen

Existing guidelines/regulation to follow

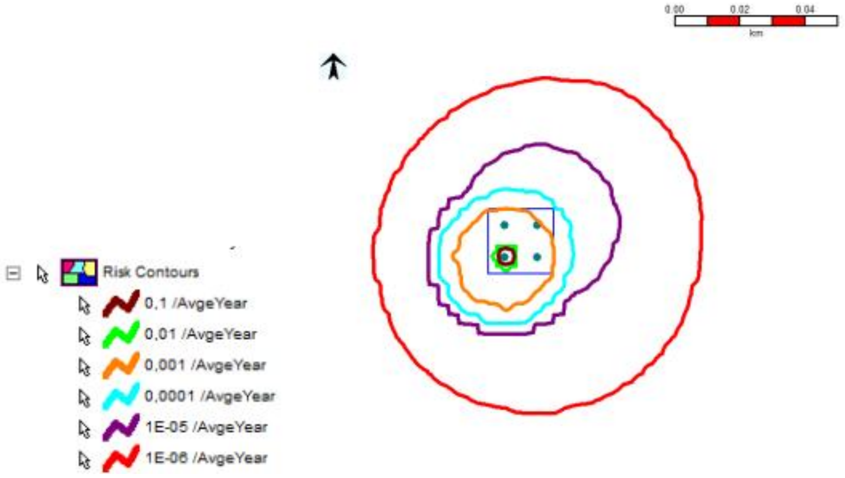
- Declaration under rubrique n°1416 (HRS specific)
- Declaration/authorisation under rubrique n° 4715 (below/above 1 tonne storage respectively)

Risk assessment methodologies - Netherlands

SEVESO Directive refers to the ISO standard:
“It may be possible to use quantitative risk assessment (QRA) and/or semi-quantitative (e.g., consequence-only) analysis instead of prescriptive requirements to allow the hydrogen fuelling station to use alternative methods which are of an equivalent, or higher, level of safety to the prescriptive requirements.” ISO 19880-1:2020

Netherlands

- Threshold values are used for QRA.
- QRA, using Safeti-NL software for the calculation of failure frequency of equipment and consequences.
- External safety risk: vulnerable objects cannot be present within a “10^{-6} contour”: zone where the chance of a fatal accident to occur is 1 in 1,000,000 per year.



Risk assessment methodologies - France

- Risk analysis is only mandatory for installations subject to the authorisation regimes – more than 1 tonnes of hydrogen storage.
- If at the end of the risk analysis one of the scenarios is in the red zone, the authorization will be refused. In addition, there must be no more than 2 scenarios in the orange zone otherwise the authorization will also be refused.
- 5 levels for the evaluation of **probability** and **severity** (based on people exposed, not fatality) of the scenario.
- Risk acceptance criteria is regulated both in the Netherlands and France. When this is not the case, a discussion is necessary within a working group to set up the risk matrix and threshold values.

Rapid Risk Ranking matrix in France

		PROBABILITY (per year)				
		A (<0.001)	B (0.01-0.001)	C (0.1-0.01)	D (1-0.1)	E (10-1)
Consequence severity	1 (Catastrophic)	H	H	H	H	H
	2(Severe loss)	M	H	H	H	H
	3 (Major damage)	M	M	H	H	H
	4 (Damage)	L	L	M	M	H
	5 (Minor damage)	L	L	L	L	M

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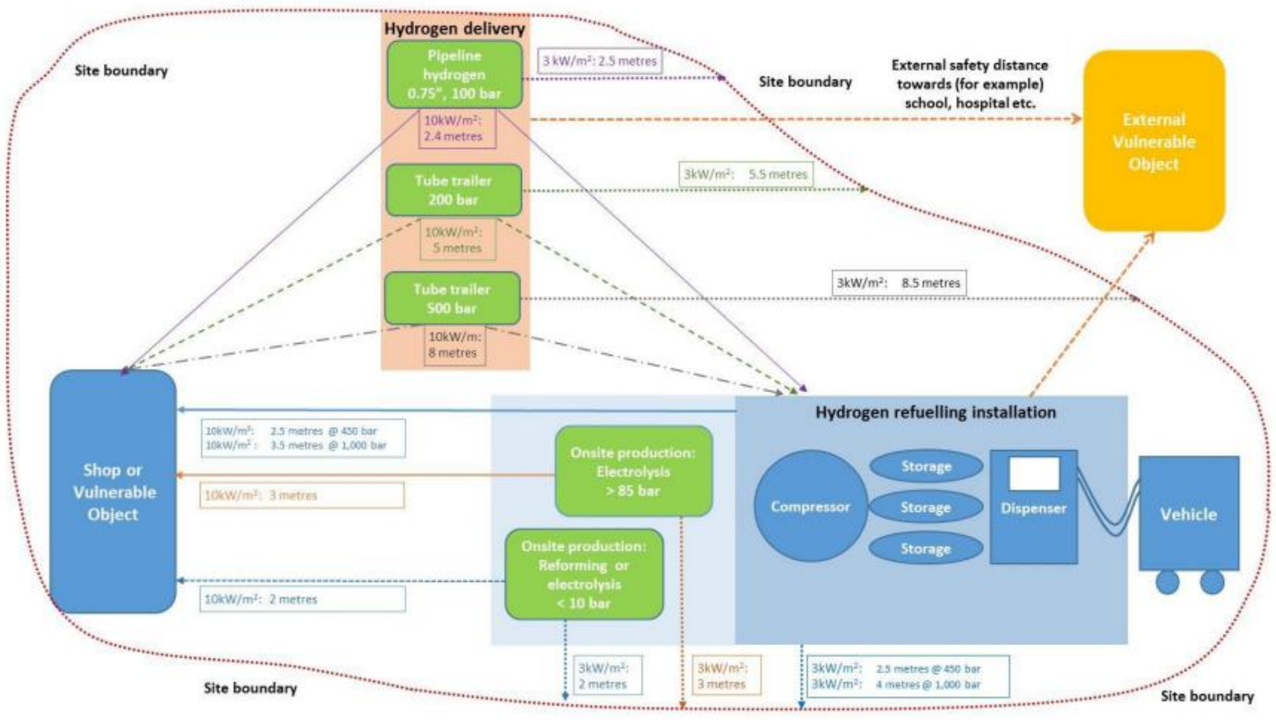
Safety distances

7. Schematic diagram of HRS illustrating separation distances PGS 35 (NL)



Remarks:
- Not to scale.
- Distances rounded to nearest 0.5 metres.

Netherlands	France
Distances between H2 storage and pipeline: 2.4-8 m (depending on pressure)	No prescribed rule
No prescribed rule	Distances between H2 equipment and other fuels: 6-14 m (depending on flow rate)

Main takeaways

- The municipalities are commonly the one-stop-shop for the granting of the permits, but will be advised by different regulatory authorities (environmental, safety) to evaluate the request

- In the Netherlands and France, HRS specific legislation is in place, normally commanding the development of a quantitative risk assessment, with available risk acceptance criteria.

- In other countries, however, these guidelines are not present, allowing more flexibility to the operator but requiring more effort in finding the right data for achieving a successful permit. Authorities will also be more cautious.

- Safety distances can be prescribed or not, but are often different from country to country. The same HRS layout is often not appropriate in different locations.

Find out more!

Safety and Permitting for Hydrogen at Multifuel Retail
MultHyFuel

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Progress

DOCUMENT NUMBER	DELIVERABLE TITLE	WEB LINK
D1.2	Permitting requirements and Risk assessment methodologies for HRS in the EU (First version)	View details
D1.4	Permitting requirements and Risk assessment methodologies for HRS in the EU (Final version)	View details
D2.2	Assessment of dispersion for high pressure H2	View details
D2.4	Fire and explosion hazard assessment summary report	View details
D3.1	State of the art – technologies	View details

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MultHyFuel

17 June 2025

MultHyfuel Final Deliverable D3.7/3.8

Ju Lynne Saw, HSE Science Division
Maria Garcia, HSE Science Division
Richard Goff, HSE Science Division
Louise O'Sullivan, HSE Science Division
Louise Corbett, HSE Science Division
Sébastien Quesnel, Engie Crigen
David Torrado, ITM Power
Nick Hart, ITM Power
Sylvaine Pique, INERIS
Benno Weinberger, INERIS
Christophe Proust, INERIS
Matteo Robino, SNAM
Markus Jenne, ZSW
Quentin Nouvelot, Engie Crigen

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Some of the research in the MultHyFuel project were undertaken by the Health and Safety Executive (HSE) and the French National Institute for Industrial Environment and Risks (INERIS) collaboratively as project partners; and under contract to MultHyFuel consortium, EU Commission, Clean Hydrogen Partnership (FCH JU) and Hydrogen Europe.

Final Deliverable Structure (D3.7/3.8)

- *'Developing Good Practice Guidelines in Project MultHyFuel'* is made up of deliverables D3.7 and D3.8 merged as 1 document.
- This output of Task 3.7 summarises the work within MultHyFuel.

Section	Title
1	Project background
2	Scope and Terms of Reference/ Caveats
3	Existing permitting requirements within Europe
4	Risk assessment methodology studied by the consortium • Likelihoods • Consequence assessment
5	Risk management and example safety barriers on an HRS forecourt
6	Recommendations and technical suggestions to inform the development and/or update of Codes and Standards as well as technical suggestions for further research and harmonisation of good practice
Appendix A	Comparative analysis between hydrogen and compressed natural gas at their respective operating conditions

Some of the research in the MultHyFuel project were undertaken by the Health and Safety Executive (HSE) and the French National Institute for Industrial Environment and Risks (INERIS) collaboratively as project partners; and under contract to MultHyFuel consortium, EU Commission, Clean Hydrogen Partnership (FCH JU) and Hydrogen Europe.
The contents of this document, including any opinions and/or conclusions expressed, or recommendations made, do not supersede current HSE or INERIS policy or guidance.

Final document Terms of Reference and Scope

- The contents of this document is based on the scope of the MultHyFuel research project.
- Where reference is made to EU Directives, this should be read as the relevant national legislation which transposes the directive.
- This document does not take into account Regulatory Consents and Land-use Planning (LUP) implications, i.e. location/siting considerations of HRSs, and how potential major hazard scenarios from the bulk storage of hydrogen might impact surrounding human populations in residential or industrial and commercial areas. These will need to be considered as part of the assessment, subject to the regulatory control in the country.
- The focus of the project's detailed research phase has been on the study of the risks from the hydrogen dispenser, but not the bulk storage, H_2 onsite production and processing. Bulk storage, H_2 onsite production and processing were considered during the preliminary risk assessment phase (Task 3.3) but are not detailed in the current deliverable; however, they will need to be considered in the siting and design of HRSs: this includes risks from H_2 trailer(s) parked for unloading at the refuelling station, and pipeline transit. Associated risks will also need to be considered and managed, subject to the country's regulatory and permissioning control. For example, HRS are likely to be in scope of the Seveso Directive, so conformance to its requirements would be required in Europe; unless inventory is managed to be below the lower tier thresholds at all times.

Final document Terms of Reference and Scope

- The experimental programme did not study liquid hydrogen (LH_2) releases.

- The results of the research reported in this document may only be specific to the assumptions made in the risk assessment, consequence modelling and conditions of the experiments conducted, e.g. release of H_2 was not sustained at constant flowrate, there was a decay with time, as a buffer tank was not used. Consequence models typically assume constant release rates. Weather conditions may also have a significant influence on the dispersion results.

- Whilst likelihood and severity determine the level of risk, techniques to determine severity (i.e. methods to estimate populations exposed to the harm) is not part of this work; instead the focus is on the consequence assessment techniques that form part of the risk assessment process.

Some of the research in the MultHyFuel project were undertaken by the Health and Safety Executive (HSE) and the French National Institute for Industrial Environment and Risks (INERIS) collaboratively as project partners; and under contract to MultHyFuel consortium, EU Commission, Clean Hydrogen Partnership (FCH JU) and Hydrogen Europe.
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Final document Terms of Reference and Scope

- The technical recommendations based on the results of this project could be applicable to similar HRS configurations and dedicated equipment as those studied within the project; and the assumptions behind these. The application to a larger scope will require dedicated risk assessments and additional validation.

- Research has been conducted at a high level and the findings and hence preliminary recommendations made in this document are at a snapshot in time. However, some of the research findings have helped identify knowledge gaps, which themselves would need addressing to properly inform Regulations, Codes and Standards (RCS); therefore it is expected that further research work would be required.

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Final Workshop
MultHyFuel - 2025

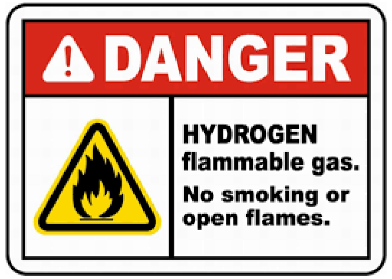
Risk Assessment Methodology

17/06/2025

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe research.

1. Objectives

- to develop best practice guidelines that can be used as a common approach to **risk assessments** (e.g. suggested methods/tools for risk modelling, Atex, safety distances)
- to determine recommendations for the safe **implementation of H2 dispensers in multi-fuel stations** (separation distances, safety barriers) to be used in standards and regulation relative to HRS
- to confirm risk **assessment assumptions by experimentations** (severity, likelihood, failure) on dispenser accessories



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Possible	Medium	Medium	High	High	Extreme
Unlikely	Low	Medium	Medium	High	High
Rare	Low	Low	Medium	High	High

2. HRS Configurations studied

MultHyFuel

After a benchmarking exercise on existing technology and equipment related to refuelling stations, three configurations were established as case studies for the MultHyFuel project

- Configuration 1: **Ready-to-deploy multifuel station**
  Configuration based on existing and implemented technologies

- Configuration 2: **Onsite H2 production multifuel station**
  Configuration based on hydrogen production meeting the required requirements

- Configuration 3: **High capacity & High filling multifuel station**
  Configuration based on future technologies that may be developed

Figure 13 - View inside the research alkaline electrolyser of the ZSW.

2. HRS Configurations studied

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- Station PFD & Layout

Configuration #1

Ready-to-deploy multifuel station

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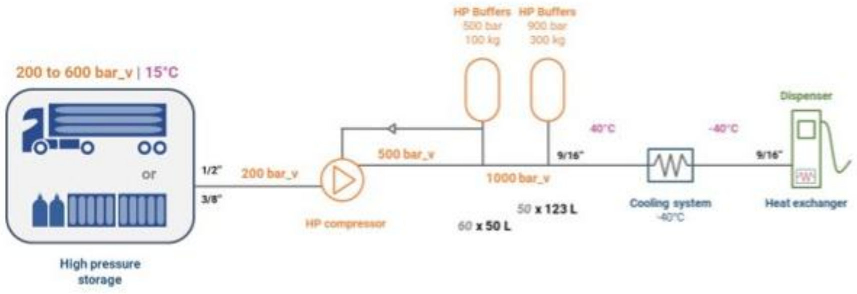

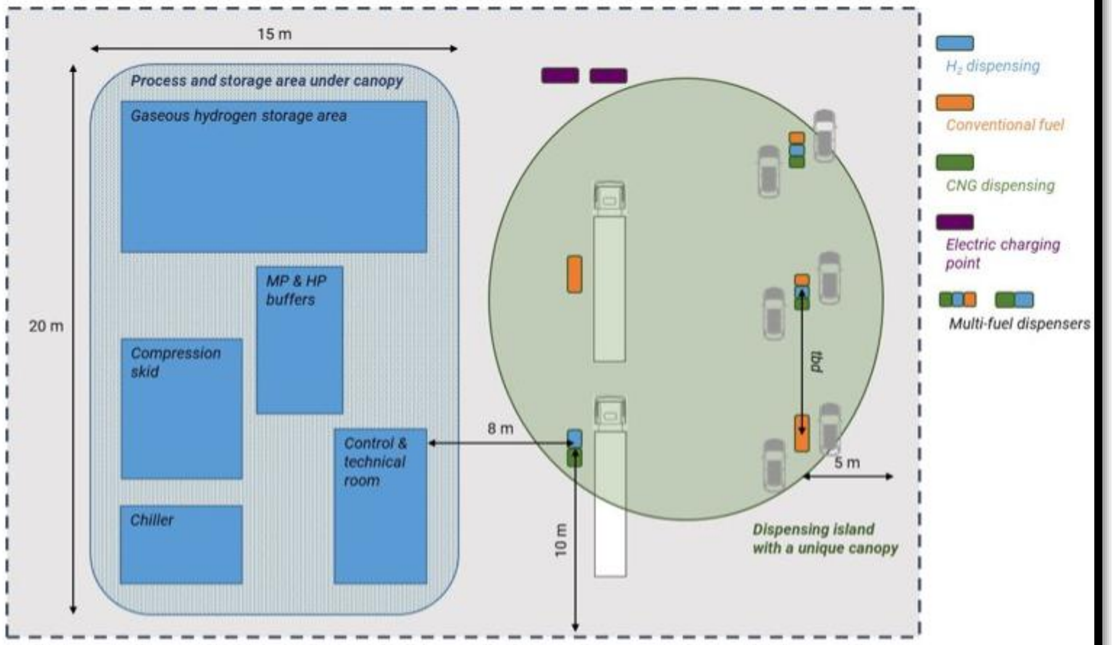

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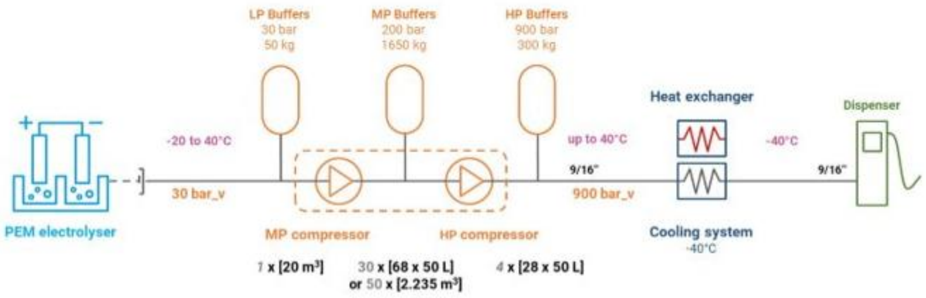
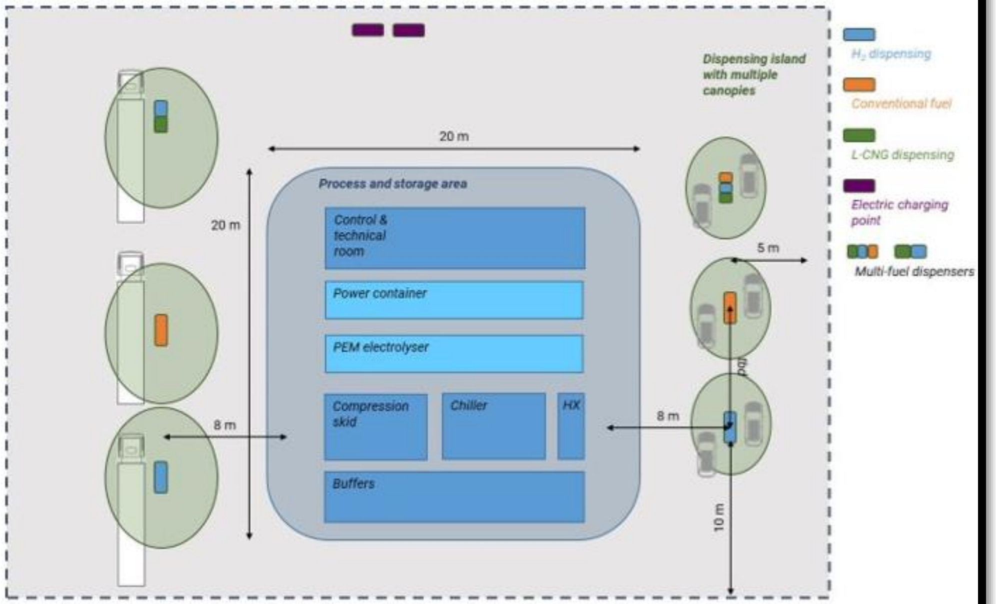
2. HRS Configurations studied

Configuration #2

On-site H_2 production multifuel station

- Station PFD & Layout





2. HRS Configurations studied

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Configuration #3

High capacity & High filling multifuel station

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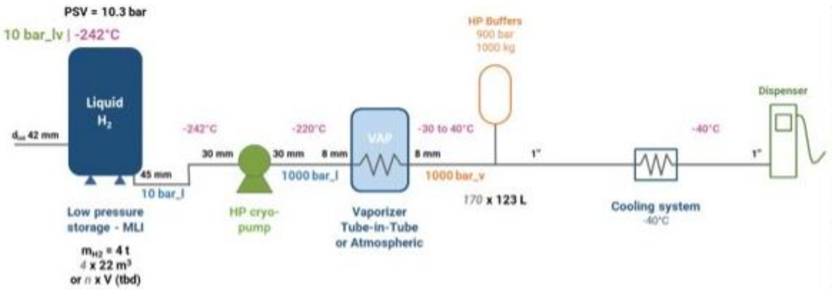
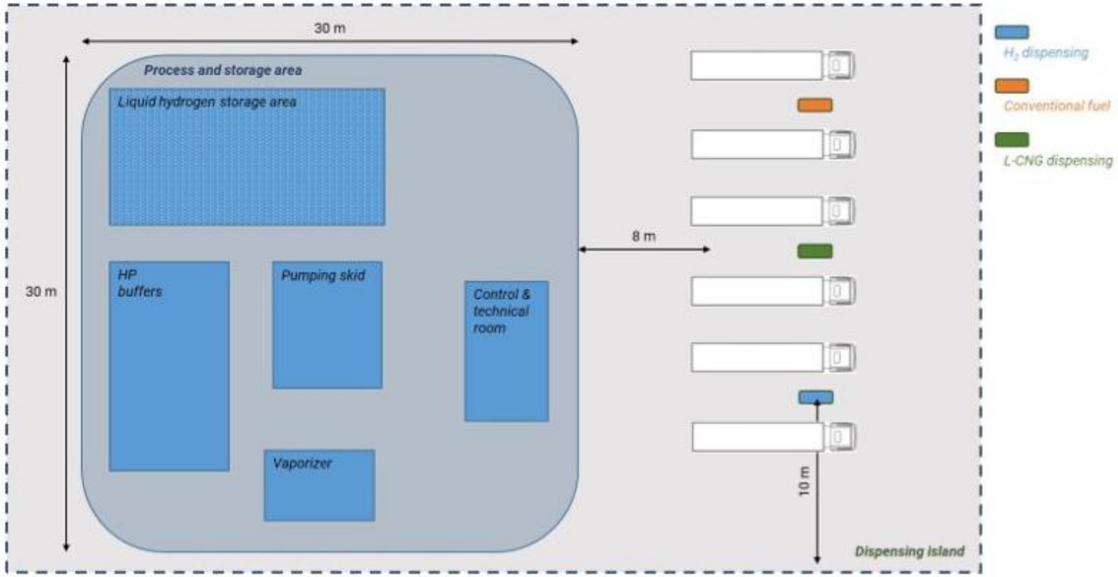
- Station PFD & Layout





Clean Hydrogen Partnership

3. State of art on risk assessment methologies

Analysis based on analysis of scientific articles and lesson learned from partners

Risk Assessment Methodologies

- HAZID/HAZOP
- APR

Databases for likelihood estimation

- Purple book
- Hyram

Modeling software

- PHAST
- Hyram

Critical Equipment

- DISPENSER
- STORAGE

Dangerous Phenomena

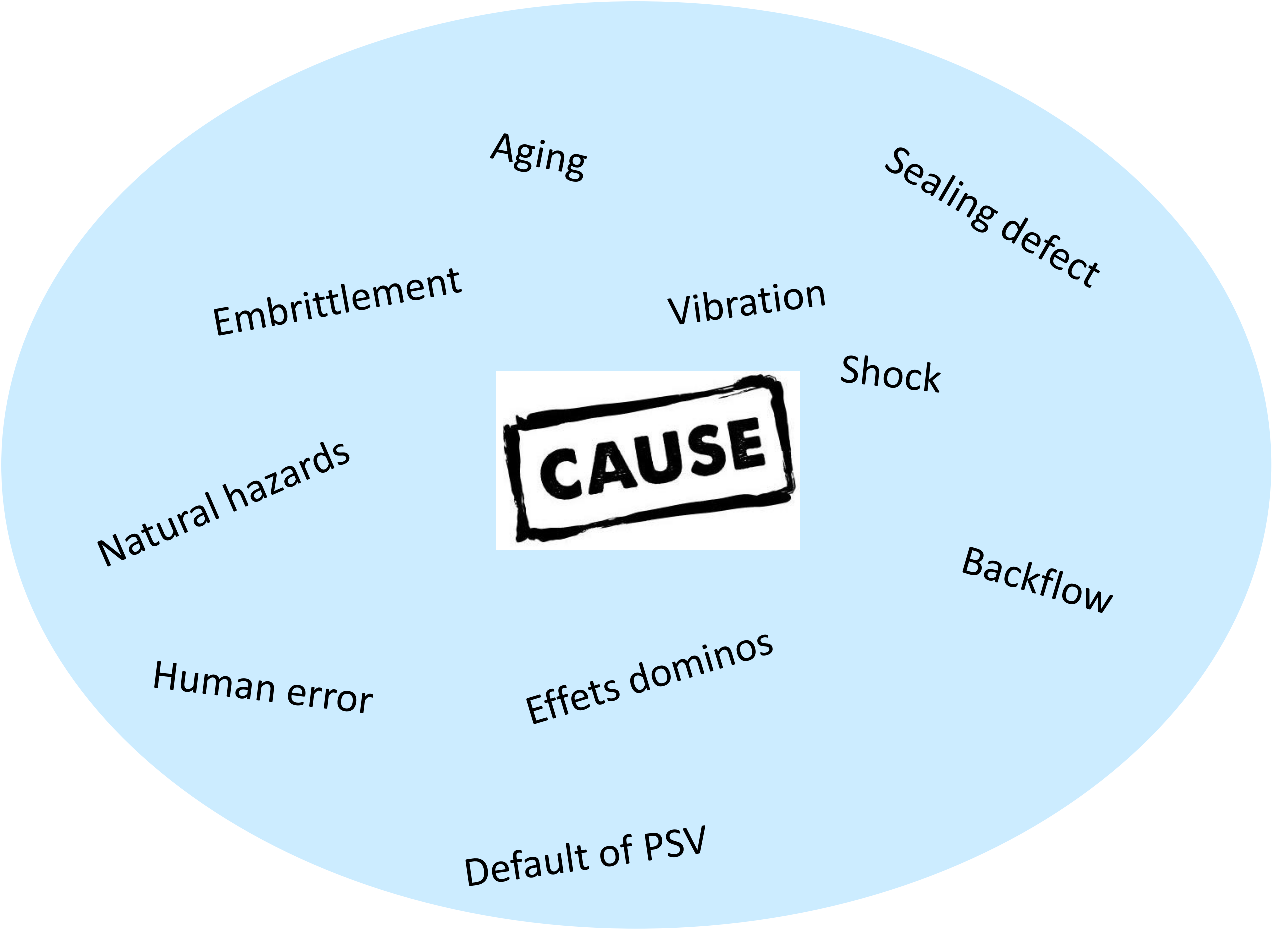
- (U) VCE/Flashfire/Jet fire and burst hydrogen
- Pool fire for LPG/diesel/ petrol
- BLEVE for LNG/LPG

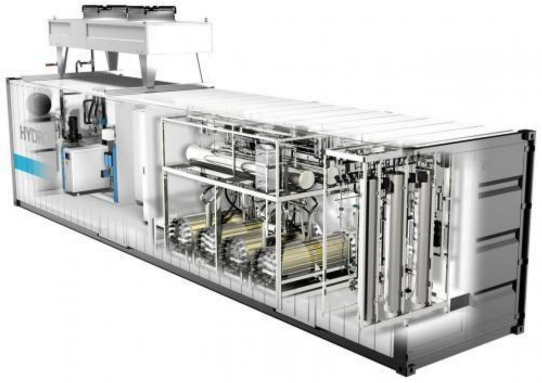
Safety Measures

- Physical protection to prevent shock
- Safety Valve to release overpressure
- Gas detection combined with an emergency stop and isolation device to limit the volume release

3. Results of PRA on different configuration

- ❑ Truck movement
- ❑ Delivery at higher pressure
- ❑ Hose connection failure
- ❑ Hydraulic circuit rupture on a truck crane…





- ❑ Membrane installation defect
- ❑ Failure in water purification…

3. Results of PRA on different configuration

SCREENING RISK MATRIX SEVERITY SCALE		
Level	***Description***	***Definition***
1	Minor	No or minor effects
2	Moderate	Injured people
3	Major	One fatality
4	Catastrophic	More than one fatality

SCREENING MATRIX LIKELIHOOD SCALE		
Level	***Description***	***Definition***
1	Rare	Might happen (unlikely to happen – no similar event known)
2	Forseeable	Could happen on a refuelling station (has occurred at least one time in industry)
3	Expectable	Can happen on a refuelling station (has occurred several times in industry)

Screening Risk Matrix	*Likelihood*			
	Level	***1***	***2***	***3***
Severity	***4***	5	6	7
	3	4	5	6
	2	3	4	5
	1	2	3	4

3. Results of PRA on different configuration

258 DPh (representative set of scenarios)

- 26 scenarios common to all configurations;
- 33 scenarios common to configurations #1 and #2;
- 2 scenarios common to configurations #1 and #3;
- 38 scenarios specific to configuration #1;
- 66 scenarios specific to configuration #2; and
- 93 critical scenarios specific to configuration #3



Dangerous phenomena/ hazardous scenarios	Configuration #1	Configuration #2	Configuration #3
Jet fire	✓	✓	✓
Flash fire	✓	✓	✓
Vapour Cloud Explosion (VCE)	✓	✓	✓
Unconfined Vapour Cloud Explosion (UVCE)	✓	✓	✓
Catastrophic rupture (e.g. mix of H_2/Air or overpressure)	✓	✓*	✓
Asphyxiation (no ignition)	✓	✓	✓
Fireball	✓	✓	✓
Hazards due to cryogenics			✓
Liquid H_2 pool fire			✓
Whipping of hose	✓	✓	✓
Unexpected fire due to oxygen enrichment		✓	

3. Results of PRA on different configuration

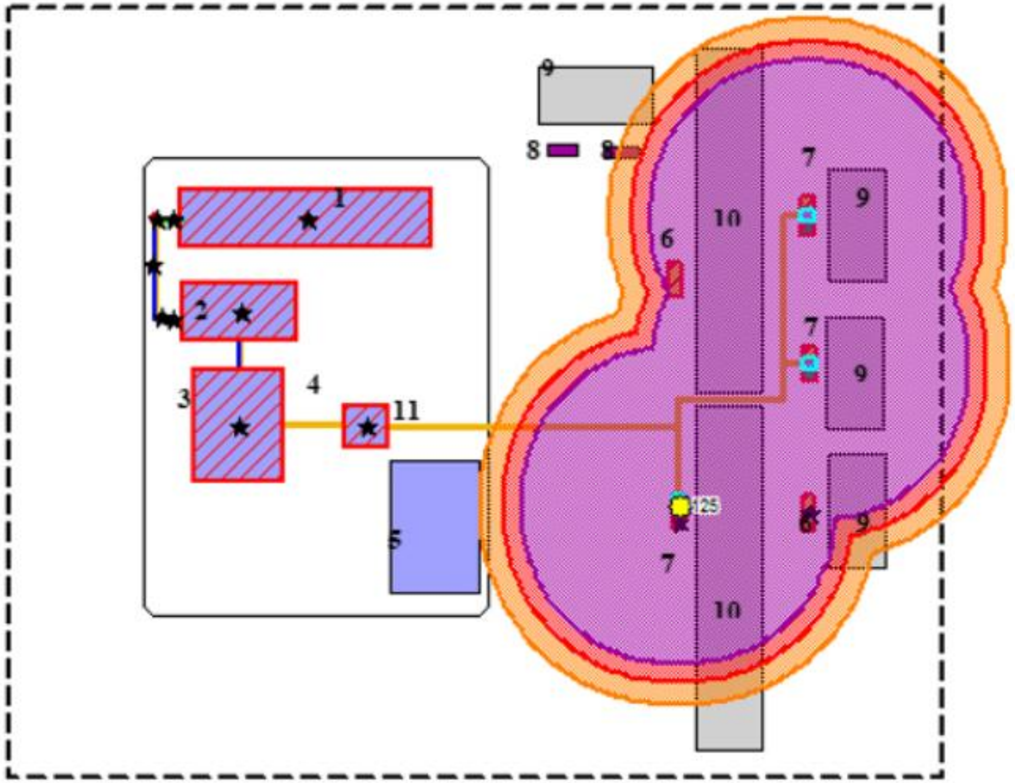
Considered equipment	Configurations #1-3
Dispenser 	- Internal release not reaching flammable limits in terms of accumulation inside the entire volume of the dispenser, but H_2 jetfire hazards considered: * without immediate ignition * with immediate ignition (flame) - Internal release reaching flammable limits (i.e. maximum concentration inside the dispenser exceeds 4% H_2) followed by ignition (VCE)
Hose	- Release with immediate (flame) or delayed ignition (UVCE) – 700 bar - Release with whipping of hose
Nozzle	- Release with immediate (flame) or delayed ignition (UVCE) – 700 bar

3. Results of PRA on different configuration

	Radiative heat fluxes	Overpressures	Whipping
Significant Lethal Effects (5%)	8 $kW.m^{-2}$	200 mbar	-
First Lethal Effects (1%)	5 $kW.m^{-2}$ or 100% LFL	140 mbar	100% hose length
Irreversible Effects	3 $kW.m^{-2}$ or 110% LFL	50 mbar	110% hose length
Indirect Effects (glass break)	-	20 mbar	-

LFL: Lower Flammability Limit

3. Results of PRA on different configuration



1	**Gaseous hydrogen storage area**	7	**Multifuel dispensers**
2	Compression skid	8	Electric charging point
3	MP & HP buffers	9	Distribution area for cars
4	Chiller	10	Distribution area for buses and heavy-duty vehicles
5	Control & technical room	11	Pipes H_2
6	Conventional fuel dispensers		

3. Results of PRA on different configuration

Severity level of consequence	Area defined by the thresholds of significant lethal effects (in French "Seuil des effets léthaux significatifs" SELS)	Area bounded by lethal effects thresholds (in French "Seuil des effets léthaux" SEL)	Area defined by the thresholds of irreversible effects (in French "Seuil des effets irréversibles" SEI)
V. Disastrous	More than 10 people exposed	More than 100 people exposed	More than 1000 people exposed
IV. Catastrophic	Less than 10 people exposed	Between 10 and 100 people exposed	Between 100 and 1000 people exposed
III. Major	At most 1 person exposed	Between 1 and 10 people exposed	Between 10 and 100 people exposed
II. Serious	No person exposed	At most 1 person exposed	Less than 10 people exposed
I. Moderate	No lethality zone outside the establishment	No lethality zone outside the establishment	

Likelihood interval	E	D	C	B	A
Frequency (per year)	$E > 10^{-5}$	$10^{-5}<D<10^{-4}$	$10^{-4}<C<10^{-3}$	$10^{-3}<B<10^{-2}$	$10^{-2}<A$

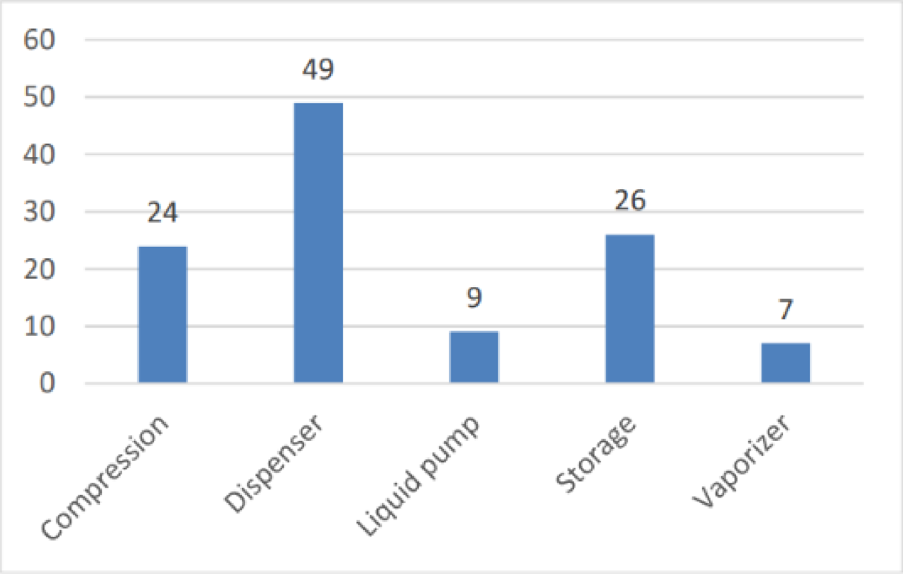
3. Results of PRA on different configuration

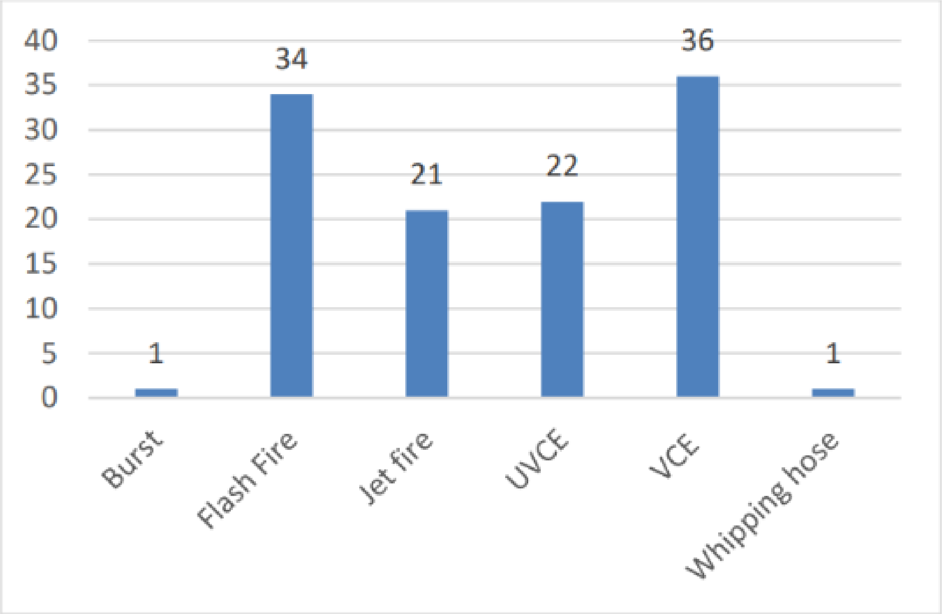
Severity in terms of harm to people exposed to the risk	Likelihood (increases from E to A)				
	E	D	C	B	A
V. Disastrous	NO (new site) / MRR (existing site)	NO	NO	NO	NO
IV. Catastrophic	MRR	MRR	NO	NO	NO
III. Important	MRR	MRR	MRR	NO	NO
II. Serious			MRR	MRR	NO
I. Moderate					MRR

3. Results of PRA on different configuration

Critical Equipment

- Dispenser
- Technical areas: storage, compressor, and equipment dedicated to LH_2





3. Results of PRA on different configuration

Table 15 - Examples of recommendations listed during the HAZID sessions (Pique, *et al.*, 2022)

Topics	Examples of recommendations
Design of the refuelling station	- Design of canopy roof to limit degree of confinement - Prefer storage with open structure on the top, or placed underground
Management of refuelling station	- Avoid unloading during thunderstorms / inclement weather conditions
Detection systems to implement	- H_2 flame and gas detection with associated emergency protocols (e.g. alarms, shutdown…)
Importance of isolation device	- Shut-off valves to isolate equipment in case of burst or dysfunction
Choice of materials	- H_2 compatible materials (e.g. for fittings, pipings, seals…) - Asphalt is prohibited to avoid air (O_2) condensation increasing combustible reactivity in case of ignition of LH_2
Location of equipment to limit domino effect	- Safe location of outlet of vent lines - Location of venting of TPRD to avoid impact on other installations
Consideration of natural hazards specific to each site	- Consider the specificities of the natural hazards (i.e. snow, rain, wind/tornado, seismic area, seaside environment) of the site
Periodic control	- Commissioning and periodic control for the integrity of H_2 equipment on the whole HRS (i.e hoses, liquid tank or tube trailer, dispenser, piping, buffer storage)
Addition of prevention and/or mitigation barriers	- Flowrate restriction orifices, break-aways, quick couplings, pressure safety valves, bursting discs, explosion panels, concentration sensors, pressure and temperature sensors, flow meter
Key parameters to monitor and control	- Temperature and pressure of the type-III and IV cylinders should be considered in the transfer protocol from compressor/buffer to fuel cell vehicle - Vibration alarm on compressor with emergency shutdown
Management of ignition sources	- Comply with Hazardous Area Classification - Explosive Atmosphere (ATEX)-certified devices

4.Likelihood

The estimation of likelihoods is a key component of risk assessment. There are a number of different approaches that can include, but are not limited to:

- ❑ **Frequency statistics** derived from past incidents, commonly held in generic failure databases;
- ❑ **Bayesian statistics** which combine both objective and subjective data, based on expert judgment or lessons learned from past incidents; and
- ❑ **the reliability of structures approach** (AFS- Approche de Fiabilité des Structures), which combines the system physical characteristics and probability of human error, independent of past incidents

The MultHyFuel project looked at the first and third methods from the bulleted list above

Likelihoods from generic failure databases

Config.	Central Feared Event (CFE)/ Top Event	Pressure	Time maximum filling (h/day)	DATABASE			DPh/ major accident event
				BEVI	Sandia	Norskeolje &gass PLOFAM	
1	Loss of H_2 containment (medium leak 10%) on hose	350 bar	3.33	A	D	E	(U)VCE Flashfire Jet fire
2			5	A	D	E	
3			21.7	A	C	D	
1		700 bar	3.33	A	D	E	
2			5	A	D	D	
3			21.7	A	C	D	
1		1000 bar	3.33	A	D	D	
2			5	A	D	D	
3			21.7	A	C	D	
1	Full bore rupture (1'' = 25.4 mm) on hose	350 bar	3.33	B	D	E	
2			5	B	D	E	
3			21.7	A	C	D	
1		700 bar	3.33	B	D	E	
2			5	A	D	D	
3			21.7	B	C	D	
1		1000 bar	3.33	B	D	D	
2			5	B	D	D	
3			21.7	A	C	D	

Likelihoods from generic failure databases

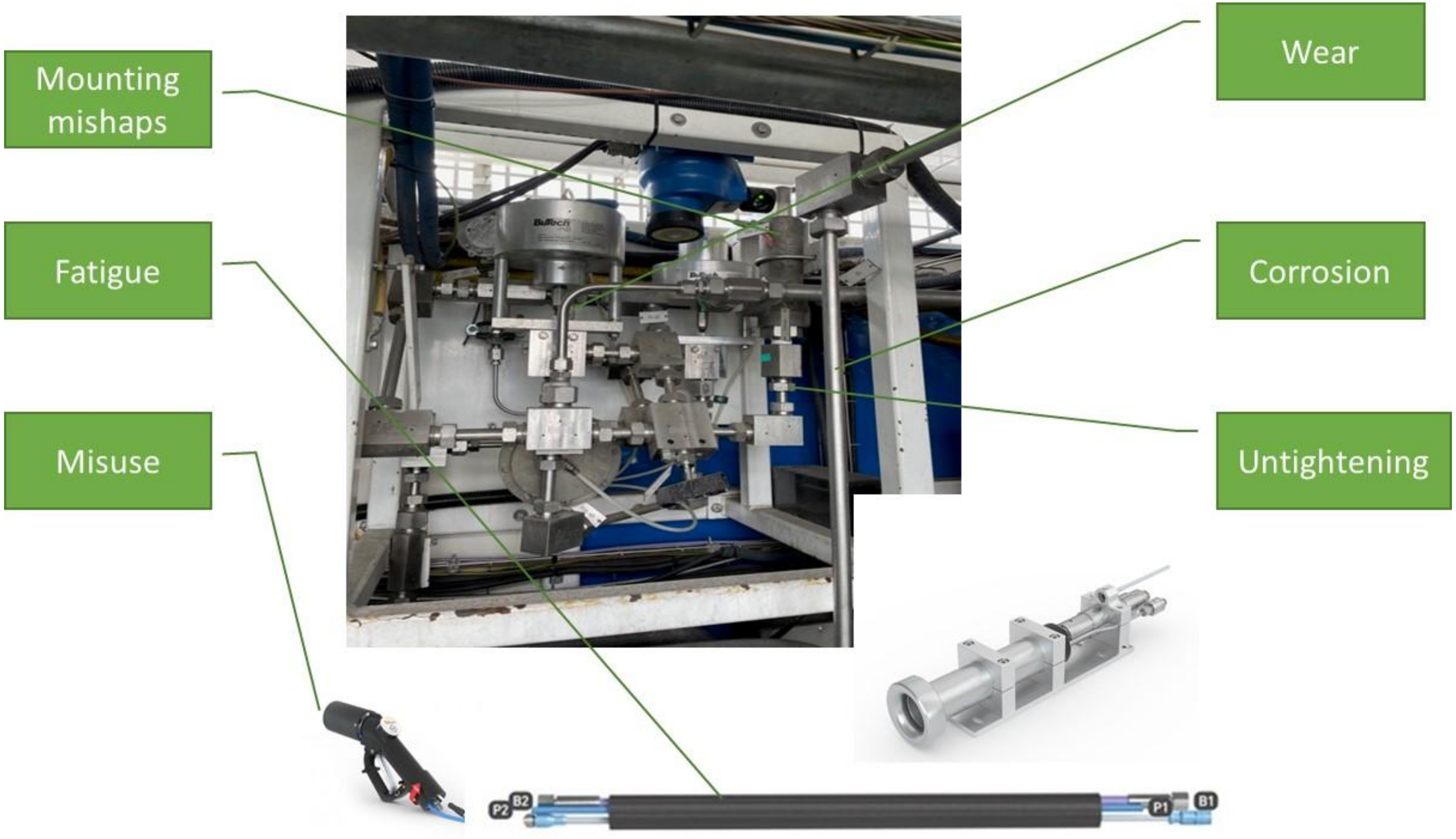
Strengths

- Relatively simple to implement;
- Relatively generalisable; and
- Considers failure modes specific to mechanical components.

Weaknesses

- The estimation of the likelihoods does not consider the initial event, the barriers and the ignition likelihood in great detail; and
- The models may not be 100% representative of reality (technology implemented in a refuelling station) and may not be adaptable to the configurations being studied

Likelihoods from the Reliability of Structures approach (AFS- Approche de Fiabilité des Structures)



Likelihoods from the Reliability of Structures approach (AFS-Approche de Fiabilité des Structures)

Component	Solicitation	$N_{cycle\text{-}op\text{-}failure}$	% fullbore	$N_{component}$	$F_{cycle\text{-}operation}$	$F_{failure\text{-}component}$
Pipe 9/16 (ID=7.9 mm)	Fatigue due to P and T cycling	10000000000	100	10	10000	1E-05
Pipe 9/16 (ID=7.9 mm)	Corrosion	1000	100	1	1	1E-03
Pipe 3/8 (ID=5.1 mm)	Fatigue due to P and T cycling	20000000000	100	10	10000	5E-06
Pipe 3/8 (ID=5.1 mm)	Corrosion	1000	100	1	1	1E-03
Pipe 1/4 (ID=2.7 mm)	Fatigue due to P and T cycling	2E+11	100	2	10000	1E-07
Pipe 1/4 (ID=2.7 mm)	Corrosion	1000	100	1	1	1E-03
Hose 3/8 (ID=4 mm)	Fatigue due to P and T cycling	10000	100	1	10000	1E-00
Hose 3/8 (ID=4 mm)	Misuse (driving on, tearing off)	200000000	100	1	10000	5E-05
Nozzle 3/8 (ID=4 mm)	Deficient maintenance (nozzle, receptacle)	50	9	1	1	2E-02
Nozzle 3/8 (ID=4 mm)	Deficient refuelling operation	100	9	1	10000	1E+02
Nozzle 3/8 (ID=4 mm)	Wear (seals)	140000	9	1	10000	7.14E-02
Nozzle 3/8 (ID=4 mm)	Misuse (driving on, tearing off)	200000000	100	1	10000	5E-05

Likelihoods from the Reliability of Structures approach (AFS-Approche de Fiabilité des Structures)

Strengths

- Takes into account failure modes specific to each mechanical component;
- Possibility of carrying out sensitivity analyses and optimisation of certain parameters;
- Quantification of specific degradation modes for each component; and
- Gives an accurate picture of the impact of each cause and mode of degradation onoverall equipment failure

Weaknesses

- Requires a good level of knowledge of mechanical and probabilistic models (both skills in statistics and probability, as well as in materials and mechanicalengineering);
- There can be significant uncertainty in the numerous input data and mathematical models;
- Models may be difficult to generalise and apply to other configurations (Requires a lot of data on equipment, processes, system environment); and
- The deterministic approach and the result correspond to a lifetime – does not allow you to benefit from the advantages of the probabilistic approach.

4. Likelihood - Conclusion

The mechanical-probabilistic ‘Reliability of Structures’ AFS approach develops a detailed analysis of the degradation modes depending on the components present in the system. This is the reason why this approach could be considered as more representative of the estimation of the likelihood for HRS accident scenarios.

However, this approach to be deployed at large scale, need to be validated via further tests and data from operational experience.

Content

Time	Title	Speaker
14.00 - 14.10	About MultHyFuel	Hydrogen Europe
14.10 - 14.20	Permitting Requirements in Europe	Hydrogen Europe
14.20 - 14.25	MultHyFuel Final Deliverable D3.7/8: Developing Good Practice Guidelines in Project MultHyFuel: Structure and Terms of Reference/ Caveats	HSE SD (Ju Lynne Saw)
14.25 - 14.40 **14.40 - 15.10** 15.10 - 15.25	Risk Assessment Approach: Methodology and Likelihoods **Consequence Analysis** •**Experimental findings** Hazardous Area Classification Example	INERIS (Sylvaine Pique) **HSE SD (recording of Louise O'Sullivan)** ITM Power (David Torrado)
15.25 - 15.40 15.40 - 15.50	6.1 Recommendations and technical suggestions for further research to inform the development and/or update of Codes and Standards: •Dispenser design •Hazardous Area Classification 6.2 Technical suggestions for further research and harmonisation of good practice	ITM Power (Nick Hart) ITM Power (David Torrado) INERIS (Sylvaine Pique)
15.50 - 16.00	Closing and Post project activities	Hydrogen Europe

MHYF: Experimental findings video

Content

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15.50 - 16.00	Closing and Post project activities	Hydrogen Europe

Hydrogen refuelling stations in a Multi-fuel context – Hazardous Area Classification Example for a hydrogen dispenser

Torrado, D.[1], Saw, J. L.[2], Quesnel, S.[3] and Hart, N.[1]

June 2025

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe research.

Background

As part of Work Package 3.6 “Safety critical scenarios, HAC & Separation Distances”, a case study assessment of Hazardous Area Classification in part of a Hydrogen Refuelling Station will be performed, using the information within the Benchmarking of WP3.6 and the relevant experimental data from Work Package 2.

The main objectives of this presentation are:

- To describe the main results in the hazardous area classification case study
    1. Internal in a dispenser example
    2. External zones around from a dispenser

Benchmarking

- **Zones definitions – Equivalent USA**
- **Hole size benchmarking**
  - IEC 60079-10-1:2020 ← **International document typically followed for hazardous area classification (used for this case study)**
  - IP 15 (2005)/IE 15 (2015)
  - IGEM SR/25 – NG and H_2 Supplement
  - Supplement blue book (HRS)
  - BCGN GN13
  - NFPA 2/NFPA 55
  - Cox et al. (1990)
- **Methodologies Hazardous area classification**
  - CFD (description)
  - Annex B, C, and D: BS EN IEC 60079-10-1:2020
  - Quadvent for determination of Zone Extents
  - E15 (Source Point/risk based approach)
- **Zones from vents**
  - Where is or isn't classified, why?
  - BS EN IEC 60079-10-1:2021 and Quadvent (assuming continuous release)
  - DVGW_G_442_2347327

BS EN IEC 60079-10-1:2020

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.

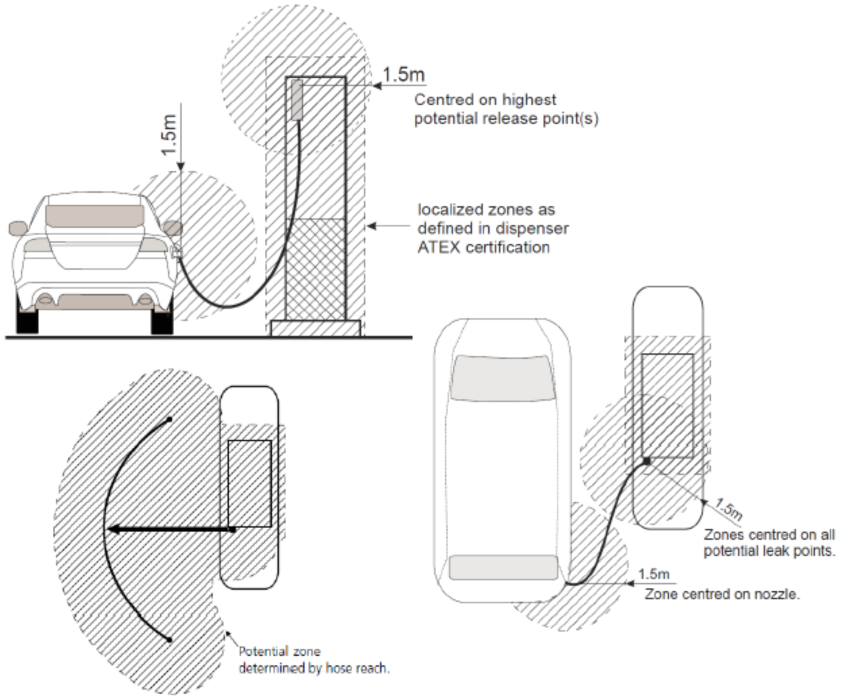
Lower values in a range: for ideal conditions, e.g. Operating at well below design ratings

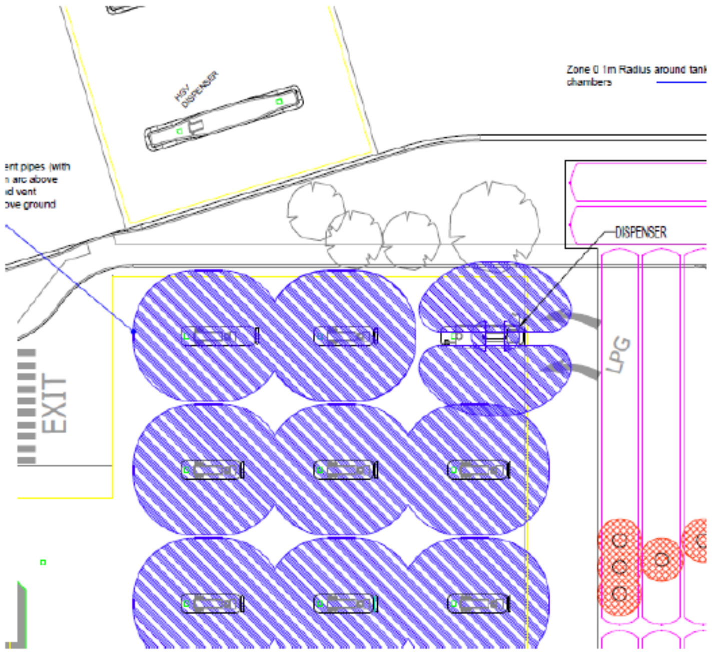
Higher values: when operating conditions are close to design ratings, or adverse conditions.

Supplement Blue Book + BCGA GN 13

MultHyFuel

HAZARDOUS AREAS AROUND DISPENSERS: HYDROGEN





Extracts from EI & APEA Blue Book hydrogen addendum

Based on 0.1 mm hole size

BCGA GUIDANCE NOTE GN 13

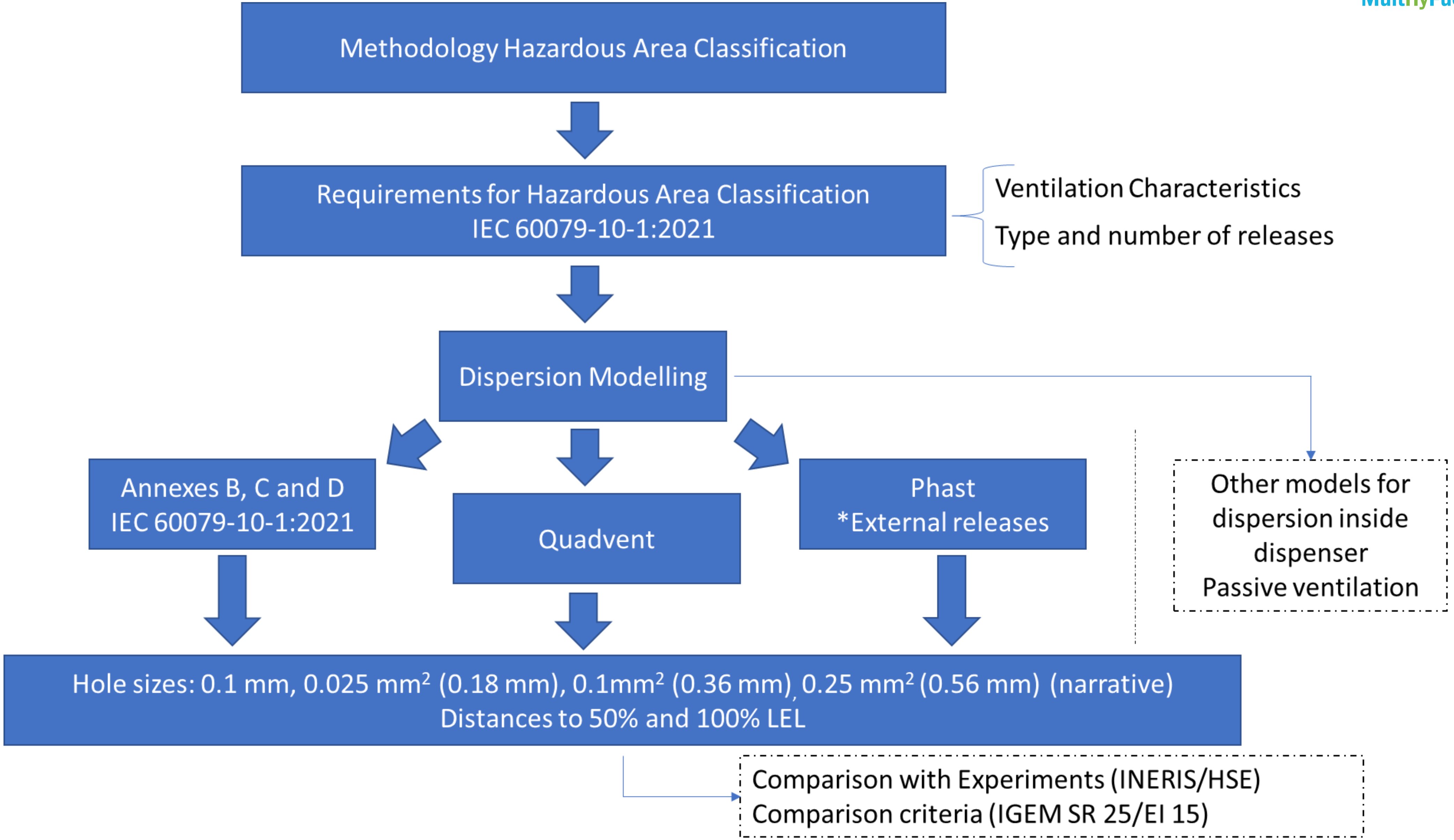
DSEAR Risk Assessment

2008

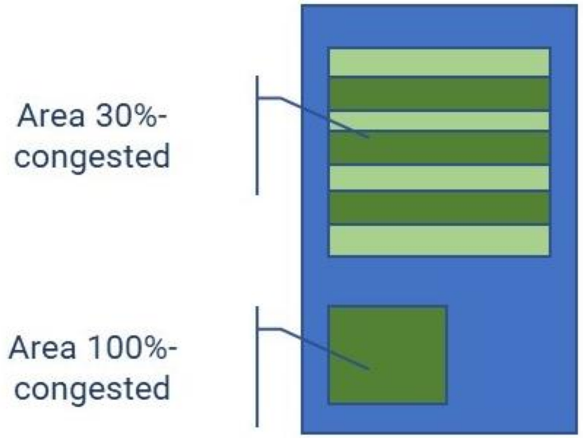
APPENDIX 1 - Release Rate Calculations

For level 1 scenarios, IP 15 2nd edition selects a realistic release source of 0.1 mm equivalent diameter for valves. This diameter is used as the leak diameter for leaks from cylinder valve outlets (cylinder valve seat not closed leak tight – a horizontal release) and for leaks from the valve gland and valve to cylinder neck joint (both likely to be vertical releases).

Main methodology



Case Study – Main Configuration



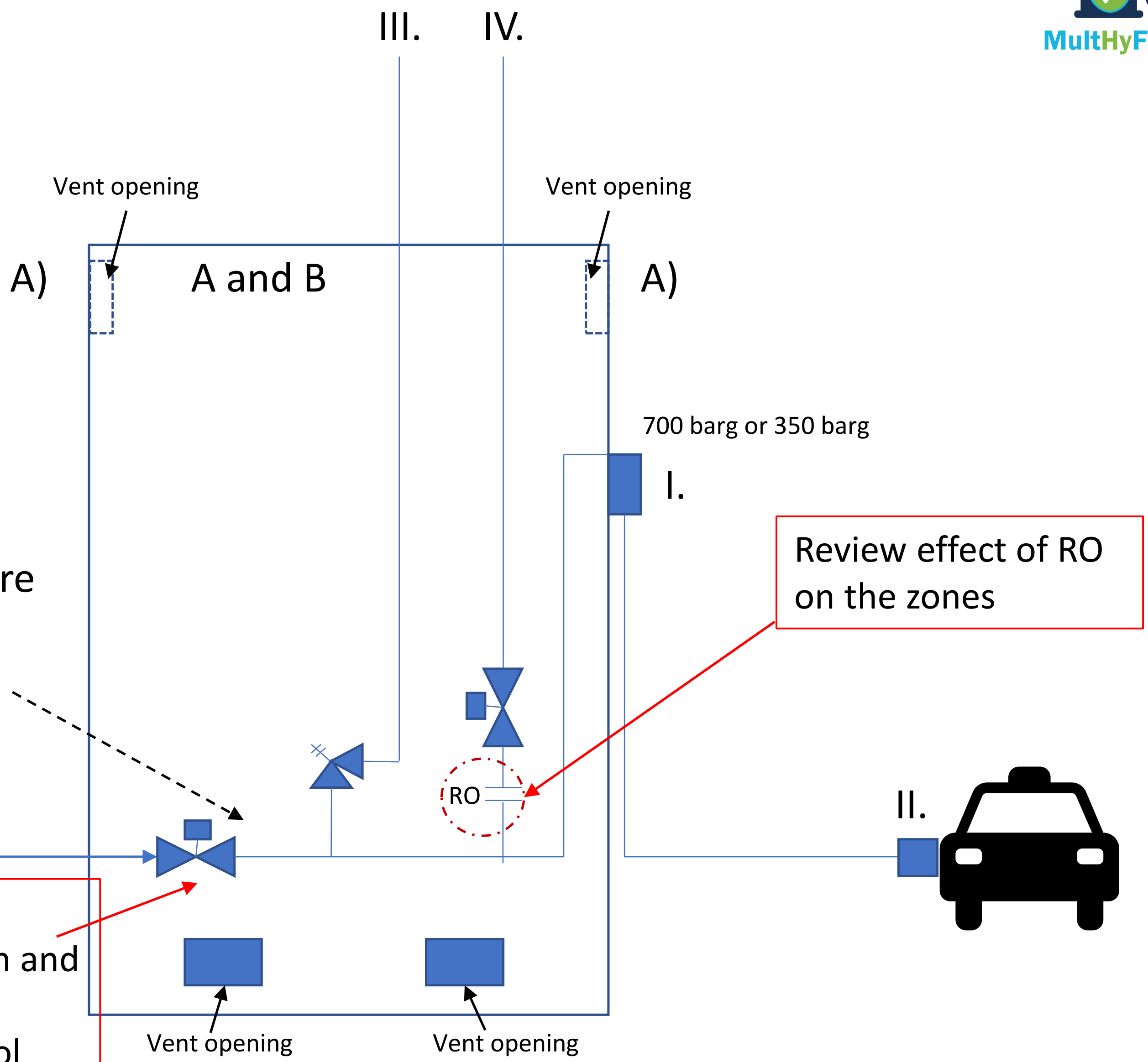
A) Natural Ventilation
- Internal release – Zoning
- Zones around vent openings (during operation/IDLE)

B) Forced Ventilation (Zone 2 – internal and external)

1. External zones
   I. Breakaway – hose
   II. Hose – Nozzle – Vehicle
   III. PRV Zone
   IV. Shutdown valve

Temperature and flow control assumed outside

Elaboration of narrative about hole size selection and pressure decay test (downstream by protocol and implications upstream)



MultHyFuel

MultHyFuel

Internal releases - Dispenser
Case Study for Hazardous Area Classification

Case Study – Main Configuration

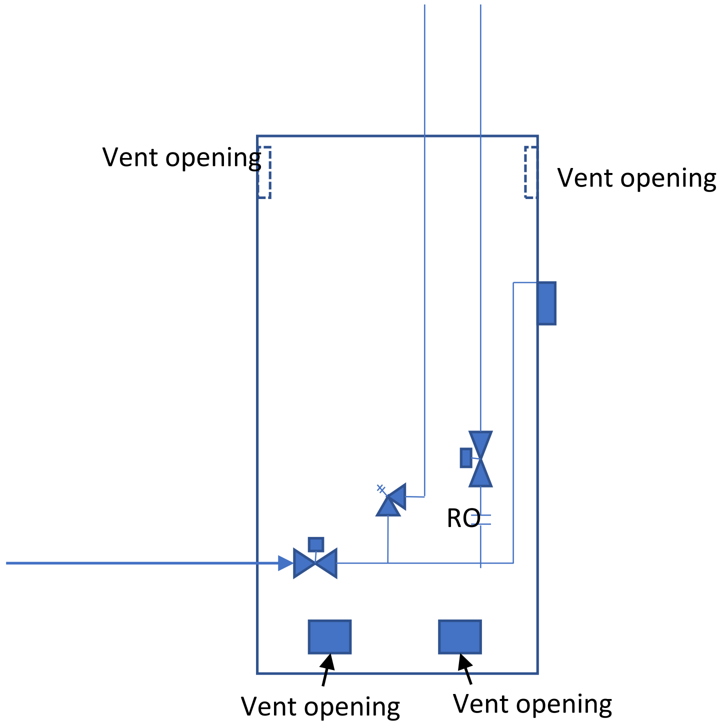


Table D.1 – Zones for grade of release and effectiveness of ventilation

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.

Table 1 — Dispensing system pressure levels and recommended component minimum pressure ratings

Hydrogen service level (HSL)	Pressure class	Maximum operating pressure (MOP)	Dispensing system maximum allowable working pressure (MAWP) Minimum component pressure rating for dispensing system components
Equal to NWP of vehicle being fuelled		*1,25 × HSL Highest pressure during normal fuelling*	*1,375 × HSL Highest permissible setpoint for dispensing system pressure protection in 8.2.2.3*
25 MPa	H25	31,25 MPa	34,375 MPa
35 MPa	H35	43,75 MPa	48,125 MPa
~~50 MPa~~	~~H50~~	~~62,5 MPa~~	~~68,75 MPa~~
70 MPa	H70	87,5 MPa	96,25 MPa
NOTE These are maximum values of MOP and MAWP, and recommended minimum component pressure ratings based on achieving the MOP needed to fuel the CHSS of the hydrogen vehicle over the full range of operating conditions, see 8.2.2.3.			

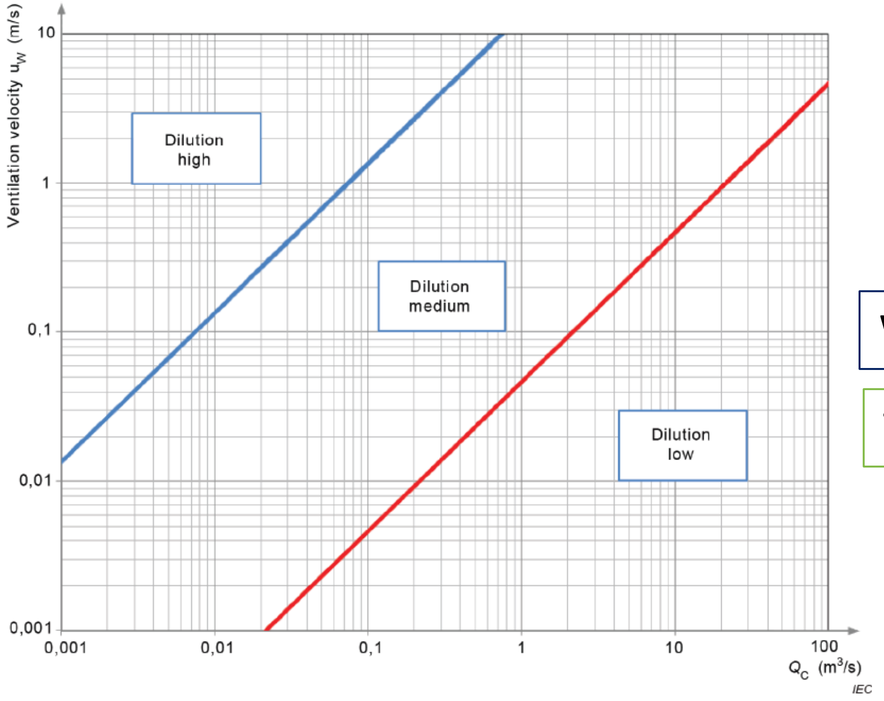
IEC 60079-10-1:2020

If concentration background concentration is above 25% LEL, the dilution shall be considered as low.

For methodology of IEC 60079-10-1:2020, degree of dilution can be determined using Figure C.1.

In this presentation, only the two extremes are shown: 875 barg as the MOP of 700 barg operation and 350 barg as the normal operation for H35 dispenser

Case Study – Main Configuration



The determination of the ventilation velocity can be performed by estimating the natural ventilation due to wind using the methodology described in section C5.2. In the subtask 2.2.1, the following extremes of ventilation wind velocity and conditions were chosen:

Wind velocities @ 10 m: 1.5 m/s and 5 m/s

$$u / u_m = K_w z^a$$

Terrain: Rural and City

Terrain	K	a
Open flat country	0.68	0.17
Country with scattered wind breaks	0.52	0.20
Urban	0.35	0.25
City	0.21	0.33

$$Q_a = C_d A_e u_w \sqrt{\Delta C_p} \; (m^3 / s)$$

Cd	0.61
Cp (lee)	-0.2
Cp(Wind)	0.7

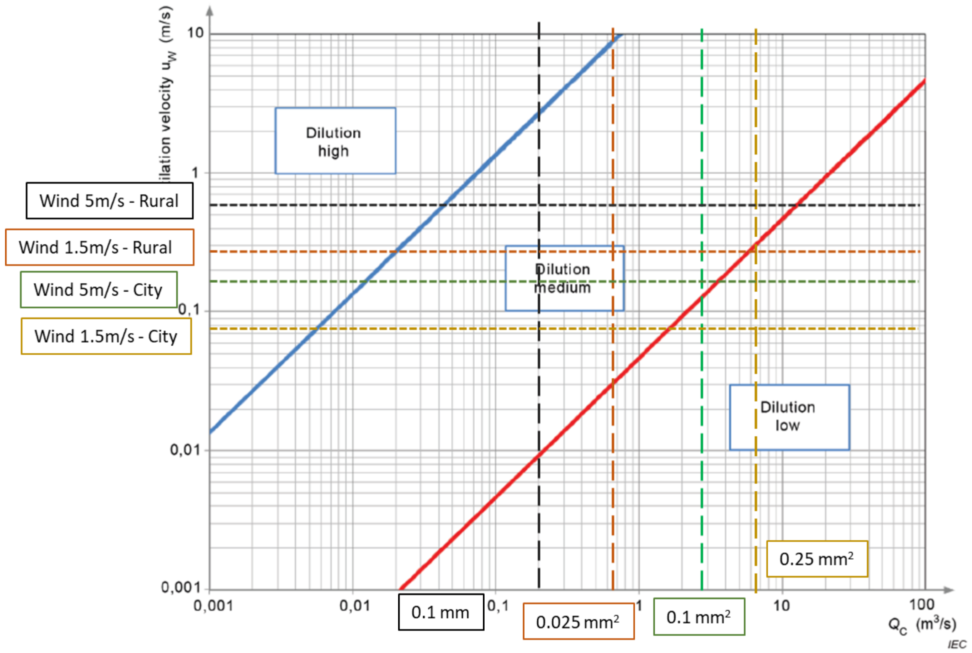
$$A_e = \sqrt{\frac{A_1^2 A_2^2}{A_1^2 + A_2^2}} \; (m^2)$$

	Ventilation m3/s	Vent velocity m/s	ACH	ACS
wind 5 m/s - Rural	0.276	0.613	1154	0.321
wind 1.5 m/s - Rural	0.083	0.184	346.3	0.096
wind 5 m/s - City	0.121	0.269	506.8	0.141
wind 1.5 m/s - City	0.036	0.080	152.6	0.042

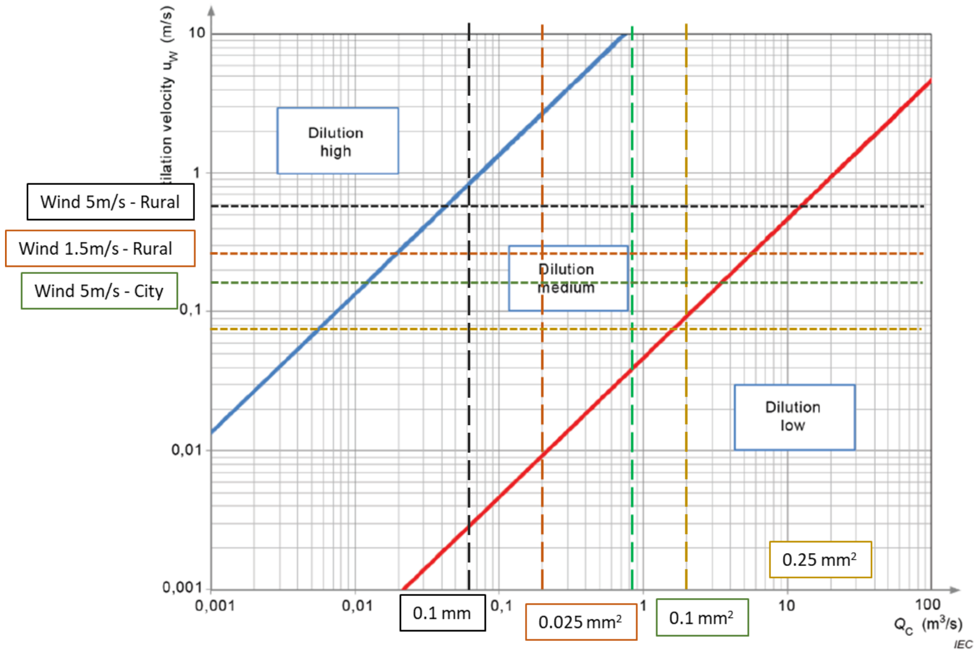
Same values obtained using Quadvent (with the same input)

Case Study – Main Configuration

875 barg (MOP H70P - ideal gas)



350 barg (NP H35P - ideal gas)



Ideal gas analysed to be able to compare with Quadvent, but calculations done for real gas as well

Condition from IEC 60079-10-1:2020 – Low dilution if background concentration > 25% LEL (1% v./v. H_2)

	0.1 mm	0.025 mm2	0.1 mm2	0.25 mm2
wind 5 m/s - Rural	1.55%	4.92%	19.68%	49.21%
wind 1.5 m/s - Rural	5.15%	16.40%	65.59%	100.00%
wind 5 m/s - City	3.52%	11.20%	44.82%	100.00%
wind 1.5 m/s - City	11.69%	37.21%	100.00%	100.00%

	0.1 mm	0.025 mm2	0.1 mm2	0.25 mm2
wind 5 m/s - Rural	0.62%	1.97%	7.89%	19.72%
wind 1.5 m/s - Rural	2.06%	6.57%	26.28%	65.70%
wind 5 m/s - City	1.41%	4.49%	17.96%	44.89%
wind 1.5 m/s - City	4.68%	14.91%	59.64%	100.00%

Case Study – Main Configuration

Conclusion

IEC 60079-10-1:2020 and Quadvent results show low dilution → **At least Zone 1 with Natural Ventilation described in the example**

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.

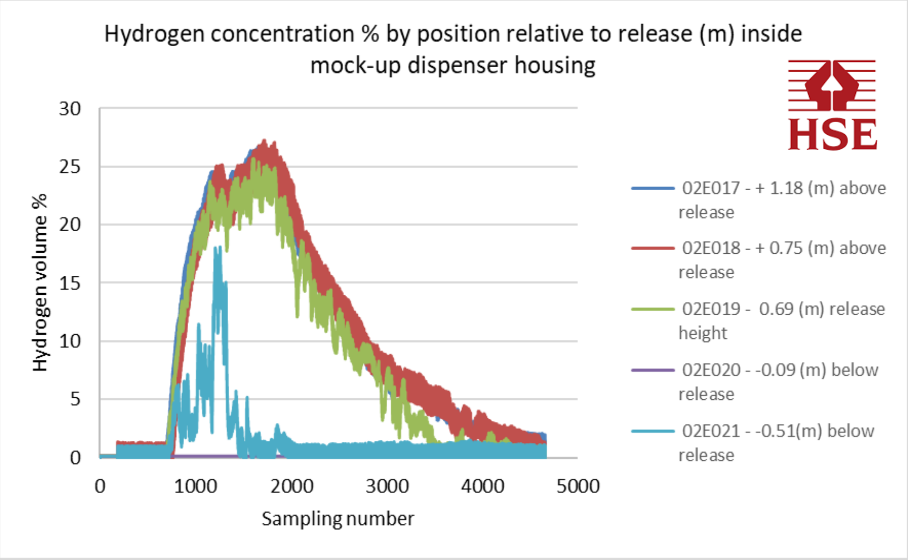
[b] The Zone 2 area created by a secondary grade of release may exceed that attributable to a primary or continuous grade of release; in this case, the greater distance should be taken.

[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.



TT04 – Dispersion of 700 barg release from 0.2 mm during approx. 60 seconds

Mock-up not same dimensions and openings, but shows considerable concentration for releases of about 1 minute

Case Study – Main Configuration

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Conclusion

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.

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'+' signifies 'surrounded by'.

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

0.01

$$X_b = \frac{f \times Q_g}{Q_g + Q_1} = \frac{f \times Q_g}{Q_2} \text{(vol/vol)}$$

?

and the air change frequency and ventilation flux are related by:

$$Q_2 = CV_0 \left(\mathrm{m^3/s}\right)$$

Ventilation flow rate (m3/s) to achieve 1% v./v. H_2 (Ideal gas)

	0.1 mm	0.025 mm2	0.1 mm2	0.25 mm2
875 barg	0.42	1.35	5.39	13.49
700 barg	0.34	1.08	4.32	10.79
438 barg	0.21	0.68	2.70	6.76
350 barg	0.17	0.54	2.16	5.40

Case Study – Main Configuration

Hole size ?

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	Leak Considerations: Typical values for the conditions at which the release opening may expand, e.g. erosion	Leak Considerations: 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) x (gasket thickness) usually ≥ 1 mm
	Flanges with spiral wound gasket or similar	0,025	0,25	(sector between two bolts) x (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 x (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.

Four hole sizes have been used for the previous calculations (0.1 mm from Supplement of the Blue book), other three from IEC 60079-10-1:2020.

Would the requirements on pressure hold test at each refuelling could justify the selection of a hole size for fittings subjected to it?

- NFPA 2 (2023) - Section 10.5.1.1.1 and 10.5.1.1.2 defines the requirement of pressure integrity checks by pressure decay monitoring prior the start and during the fuelling of the vehicle
- SAE J2601 – Section 5 suggest the incorporation of leak checks during start-up.

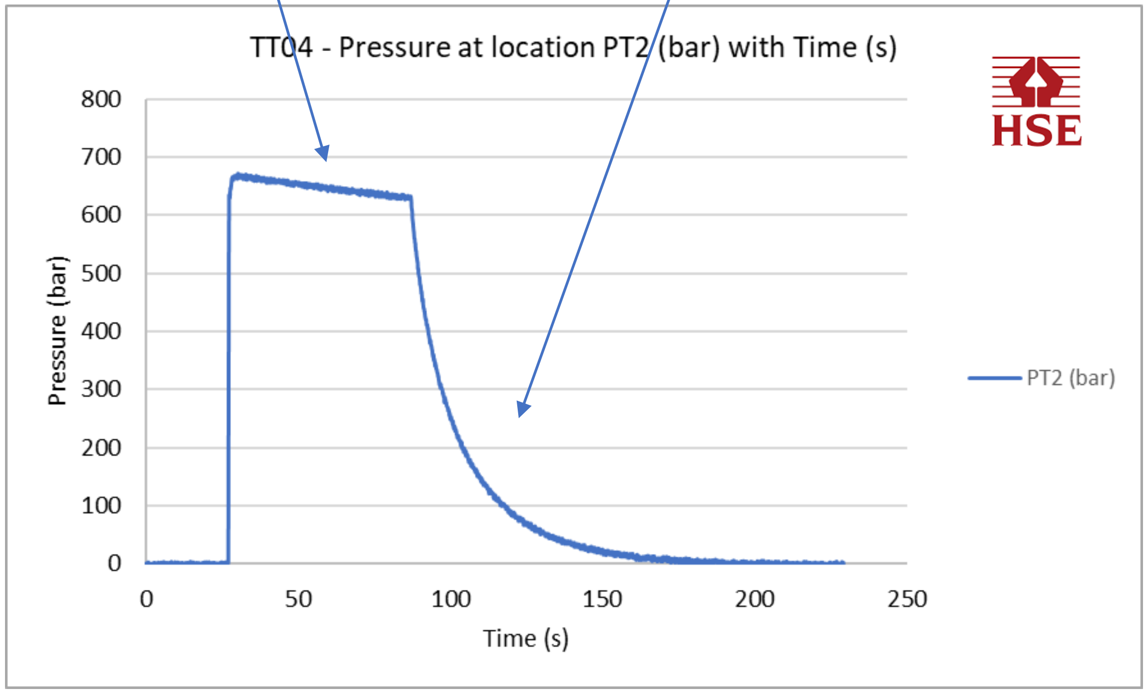
Control systems according to a Functional Safety standard may reduce the potential for a source of release and/or the quantity of a release (e.g. batch sequence controls, inerting systems). Such controls may therefore be considered where relevant to the hazardous area classification.

Case Study – Main Configuration

Experimental result

Release within mock-up connected to High Pressure Storage

Release within mock-up after isolation of storage



TT04 – Dispersion of 700 barg release from 0.2 mm during approx. 60 seconds

When there is a 0.2 mm leak during a pressure integrity check before refueling, decrease of pressure suggest it would be detected.

The result suggests that a recurrent integrity check can justify small leaks of at least 0.025 mm^2 (0.18 mm), as exponential releases would potentially be detected

However, for fittings are equipment within the dispenser that are not subjected to recurrent pressure integrity checks at each vehicle refuelling, it may not be possible to justify small hole sizes.

Potential recommendation for fittings that are not part of the integrity check

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External Zones – Leaks from Fittings
Case Study for Hazardous Area Classification

November 2023

Leaks from fittings (external)

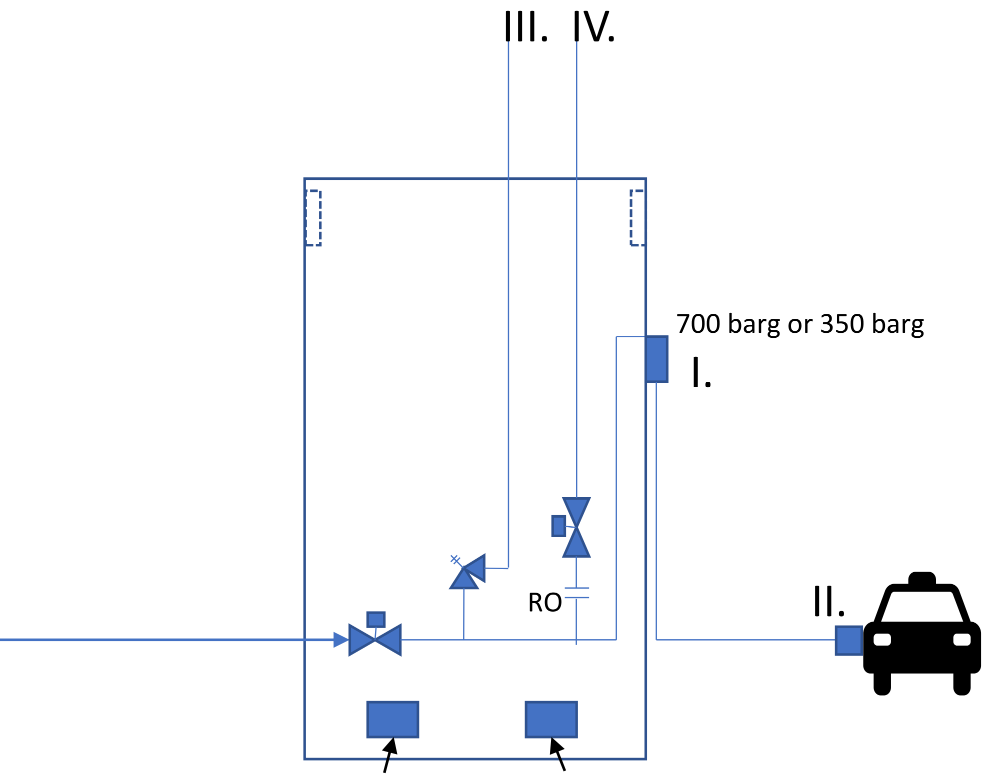

Table B.1 – Suggested hole cross sections for secondary grade of releases

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 (mm²)	S (mm²)	S (mm²)
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) x (gasket thickness) usually ≥ 1 mm
	Flanges with spiral wound gasket or similar	0,025	0,25	(sector between two bolts) x (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 mm² [d]
	Pressure relief valves[b]	0,1 x (orifice section)	NA	NA
Sealing elements on moving parts at high speed	Pumps and compressors[e]	NA	≥ 1 up to 5	To be defined according to Equipment Manufacturer's Data and/or Process Unit Configuration but not less than 5 mm² [d and e]

Annexes B, C and D
IEC 60079-10-1:2021

Quadvent

Phast
*External releases

Other models for dispersion inside dispenser
Passive ventilation

Hole sizes: 0.1 mm, 0.025 mm² (0.18 mm), 0.1mm² (0.36 mm), 0.25 mm² (0.56 mm) (narrative)
Distances to 50% and 100% LEL

Comparison with Experiments (INERIS/HSE)
Comparison criteria (IGEM SR 25/EI 15)

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Phast simulation

Leak size : 0.1mm

875 bar

Horizontal

Horizontal leak At 1m heigth	D-0,5	D-5	F-1,5	G-1
Distance max from leak @ 2% H2 (m)	1,28	1	1,27	1,35
Distance max from leak @ 4%H2 (m)	0,64	0,57	0,63	0,62

Case Study – Main Configuration

0.1 mm

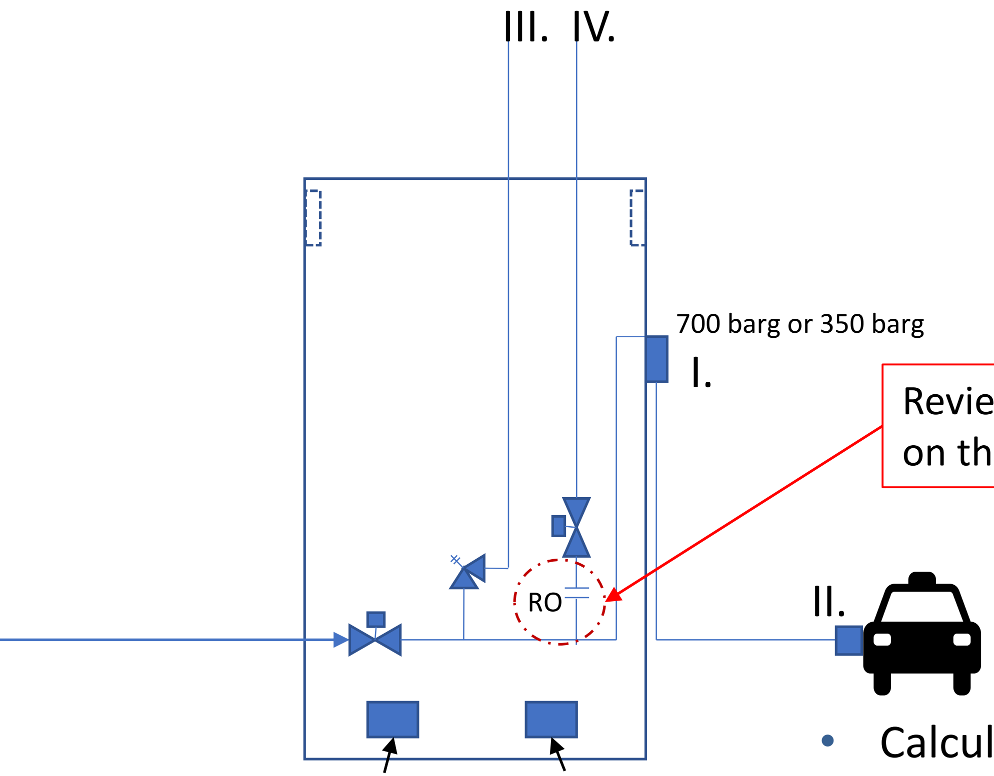
	Quadvent		IEC 60079-10-1:2020 (ideal)		IEC 60079-10-1:2020 (real)		Phast (horizontal)	
Pressure (barg)	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL
875 barg	0.966 m	1.973 m	/	Jet : 1 m Diffusive: 2 m	/	Jet : 1 m Diffusive: 1.7 m	G – 1: 0.62 m	G – 1: 1.35 m
700 barg	0.864 m	1.765 m	/	Jet : 1 m Diffusive: 1.8 m	/	Jet : 1 m Diffusive: 1.6 m	G – 1: 0.58 m	G – 1: 1.25 m
438 barg	0.684 m	1.397 m	/	Jet : 1 m Diffusive: 1.5 m	/	Jet : 1m Diffusive: 1.4 m	G – 1: 0.49 m	G – 1: 1.1 m
350 barg	0.612 m	1.249 m	/	Jet : 1m Diffusive: 1.4 m	/	Jet : 1m Diffusive: 1.3 m	G – 1: 0.45 m	G – 1: 1.04 m

0.025 mm² (0.18 mm)

	Quadvent		IEC 60079-10-1:2020 (ideal)		IEC 60079-10-1:2020 (real)		Phast (horizontal)	
Pressure (barg)	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL	Distance to LFL	Distance to ½ LFL
875 barg / -40°C (Tamb 15°C)	1.72 m	3.511 m	Jet : 1.7 m Diffusive: 3.4 m	/	Jet : 1.6 m Diffusive: 3.1 m		G – 1: 1.25 m	D– 0.5: 2.23 m
875 barg / -15°C (Tamb 15°C)	1.63 m	3.34 m	Jet : 1.7 m Diffusive: 3.4 m	/	Jet : 1.5 m Diffusive: 2.9 m		G– 1: 1.21 m	D– 0.5: 2.16 m
875 barg / -40°C (Tamb 35°C)	1.78 m	3.64 m	Jet : 1.8 m Diffusive: 3.5 m	/	Jet : 1.6 m Diffusive: 3.2 m		G – 1: 1.29 m	D– 0.5: 2.31 m
700 barg	1.54 m	3.141 m	Jet : 1.6 m Diffusive: 3.2 m	/	Jet : 1.5 m Diffusive: 2.9 m		G – 1: 1.2 m	G – 1: 1.9 m
438 barg	1.22 m	2.49 m	Jet : 1.3 m Diffusive: 2.5 m	/	Jet : 1.1 m Diffusive: 2.2 m		D– 0.5: 1 m	D– 0.5: 1.7 m
350 barg	1.09 m	2.22 m	Jet : 1.2 m Diffusive: 2.2 m	/	Jet : 1 m Diffusive: 2.1 m		G – 1: 0.84 m	G – 1: 1.54 m

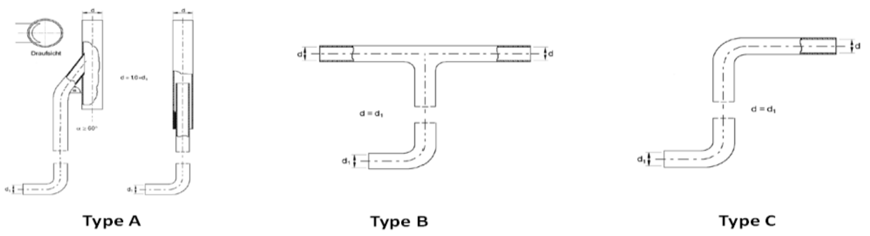
External Zones – Depressurization line
Case Study for Hazardous Area Classification

Case Study – Main Configuration

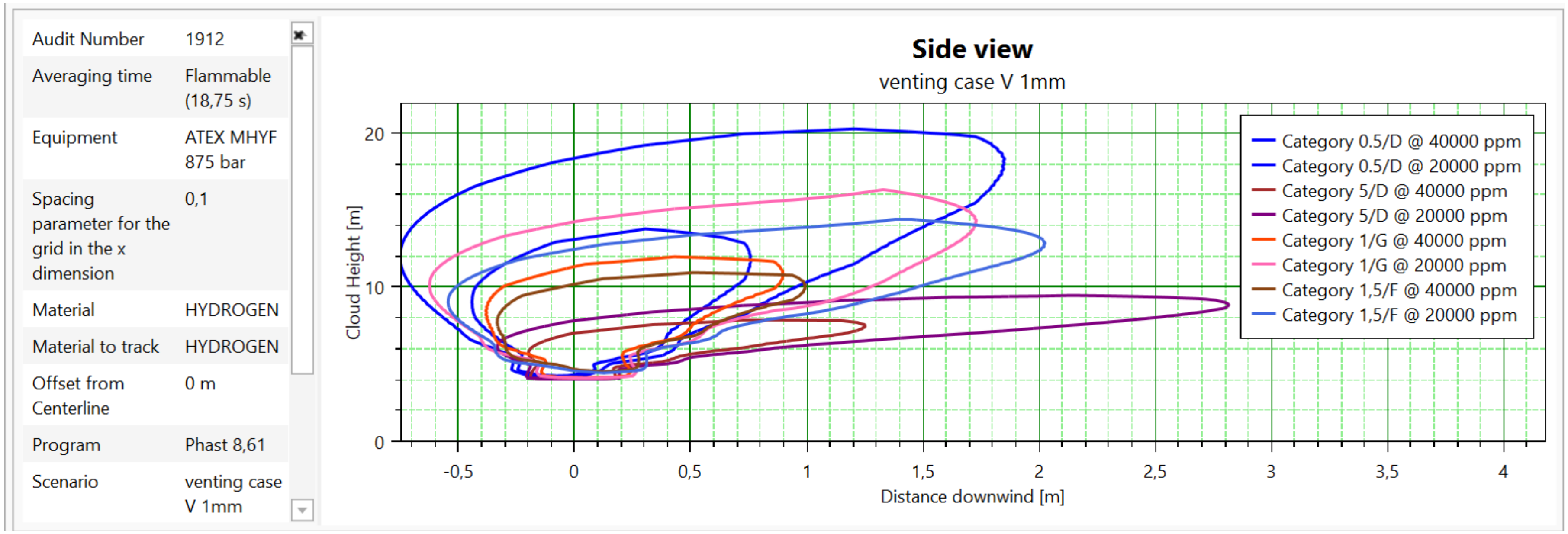


Flow rate (kg/s)		RO diameter (mm)		
		1	2	Full bore
Pressure (barg)	875	2.75E-02	1.10E-01	2.75E+00
	700	2.31E-02	9.22E-02	2.31E+00
	438	1.54E-02	6.17E-02	1.54E+00
	350	1.28E-02	5.13E-02	1.28E+00

- Calculations performed using method in Annexes B, C and D of BS EN IEC 60079-10-1
- Phast calculations – Atmospheric conditions and release direction



Example of Phast results



RO : 2mm
Flowrate : 1.1e-1kg/s

Diameter vent outlet : 10mm
875 bar

Vertical

Horizontal release at 4m heigth	D-0,5	D-5	F-1,5	G-1
Distance max from vent outlet @ 2% H2 (m)	(20 –4)m	(9 –4)m	(14 –4)m	(16 –4)m
Distance max from vent outlet @ 4%H2 (m)				

Case Study – Main Configuration (venting)

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*Vertical extent calculated from the release point (outlet of vent)			Scenario					
			875 barg			700 barg		
Release conditions			RO – 1 mm	RO – 2mm	Full Bore	RO – 1 mm	RO – 2mm	Full Bore
Rate of release	(Wg)	kg/s	2.75E-02	1.01E-01	2.75E00 (*1.45E00 calculated by PHAST and 3.63E00 by Quadvent*)	2.31E-2	9.22E-02	2.31E00 (*1.21E00 calculated by PHAST and 2.90E00 by Quadvent*)
Phast distances * to 50% LFL	0.5/D	m	Max horiz.: 12,6m Max. vert: 8,5 m	Max horiz.: 23m Max. vert: 16m	*Max horiz.: 73m Max. vert: 56m*	Max horiz.: 12m Max. vert: 8m	Max horiz.: 21,5m Max. vert: 15m	*Max horiz.: 68m Max. vert: 51m*
	5/D	m	Max horiz.:8,5 m Max. vert:3m	Max horiz.: 15 m Max. vert: 5m	*Max horiz.: 51m Max. vert: 19m*	Max horiz.: 8m Max. vert: 2,5m	Max horiz.: 14m Max. vert: 5m	*Max horiz.:45m Max. vert: 17m*
	1/G	m	Max horiz.:10m Max. vert:6,5m	Max horiz.: 19 m Max. vert: 12m	*Max horiz.: 58m Max. vert:36m*	Max horiz.: 9,5m Max. vert: 6m	Max horiz.: 17,5m Max. vert: 11m	*Max horiz.: 54m Max. vert: 33m*
	1.5/F	m	Max horiz.:10,2m Max. vert: 5,5m	Max horiz.: 18,5m Max. vert: 10m	*Max horiz.:59m Max. vert:31m*	Max horiz.: 9,5m Max. vert: 4m	Max horiz.: 17m Max. vert: 9,5m	*Max horiz.:55m Max. vert: 29m*
IEC 60079-10-1:2020 LFL (safety factor of 2 on Q_c)**			Jet: 9 m Diffusive: 18 m	Outside the range	Outside the range	Jet: 8 m Diffusive: 16 m	Outside the range	Outside the range
Quadvent 50% LFL			19.1 m	38.2 m	191 m	17.1 m	34.1 m	170 m

** Choked flow equation calculated using estimated Z at P,T of the gas (real gas)

*Vertical extent calculated from the release point (outlet of vent)			Scenario					
			438 barg			350 barg		
Release conditions			RO – 1 mm	RO – 2mm	Full Bore	RO – 1 mm	RO – 2mm	Full Bore
Rate of release	(Wg)	kg/s	1.54E-2	6.17E-2	1.54E00 (*0.8E00 calculated by PHAST and 1.82E00 by Quadvent*)	1.28E-2	5.13E-02	1.28E00 (*0.66E00 calculated by PHAST and 1.45E00 by Quadvent*)
Phast distances* to 50% LFL	0.5/D	m	Max horiz: 10m Max. vert: 6,5m	Max horiz.: 18,5m Max. vert: 12,5m	*Max horiz.: 58m Max. vert: 42m*	Max horiz.: 9,5m Max. vert: 6m	Max horiz.: 17m Max. vert: 11m	*Max horiz.: 53m Max. vert: 39m*
	5/D	m	Max horiz: 7m Max. vert: 2m	Max horiz.: 12m Max. vert: 4m	*Max horiz.: 36m Max. vert: 14m*	Max horiz.: 6,5m Max. vert: 2m	Max horiz.: 11m Max. vert: 4m	*Max horiz.: 32m Max. vert: 13m*
	1/G	m	Max horiz.: 8m Max. vert: 5m	Max horiz.: 15m Max. vert: 9m	*Max horiz.: 46m Max. vert: 28m*	Max horiz.: 7,5m Max. vert: 4,5m	Max horiz.: 14m Max. vert: 9m	*Max horiz.: 42m Max. vert: 26m*
	1.5/F	m	Max horiz.: 8m Max. vert: 4m	Max horiz.: 14,5m Max. vert: 8m	*Max horiz.: 46m Max. vert: 24m*	Max horiz.: 7,5m Max. vert: 4m	Max horiz.: 13,5m Max. vert: 9m	*Max horiz.: 42m Max. vert:22m*
IEC 60079-10-1:2020 LFL (safety factor of 2 on Q_c)**			Jet: 7 m Diffusive: 14 m	Outside the range	Outside the range	Jet: 6 m Diffusive: 12 m	Jet: 13 m Diffusive: 24 m	Outside the range
Quadvent 50% LFL			13.5 m	27.1 m	135 m	12 m	24.1 m	120 m

** Choked flow equation calculated using estimated Z at P,T of the gas (real gas)

- Choice of type of vent has an effect on the extent, Phast allows to analyse that effect
- IEC 60079-10-1:2020 and Quadvent result in a distance, and the zone representation would depend on assessment from the designer (circle, cylinder, ?)

Case Study – Main Configuration (venting)

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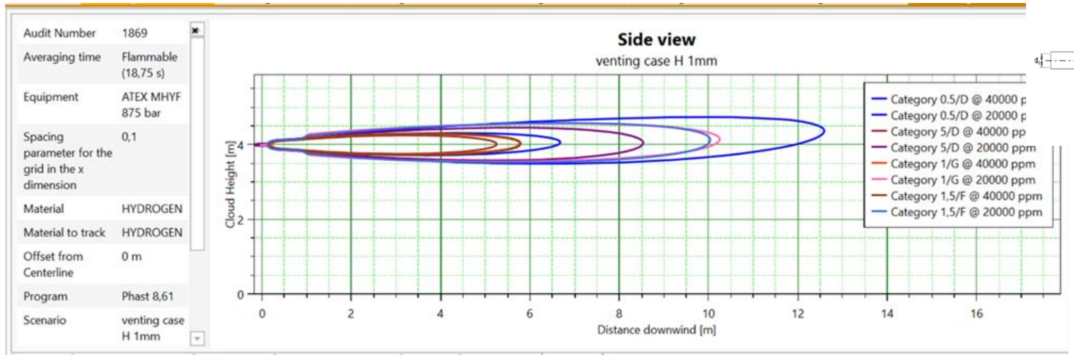
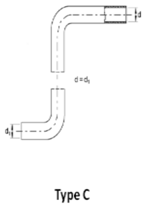
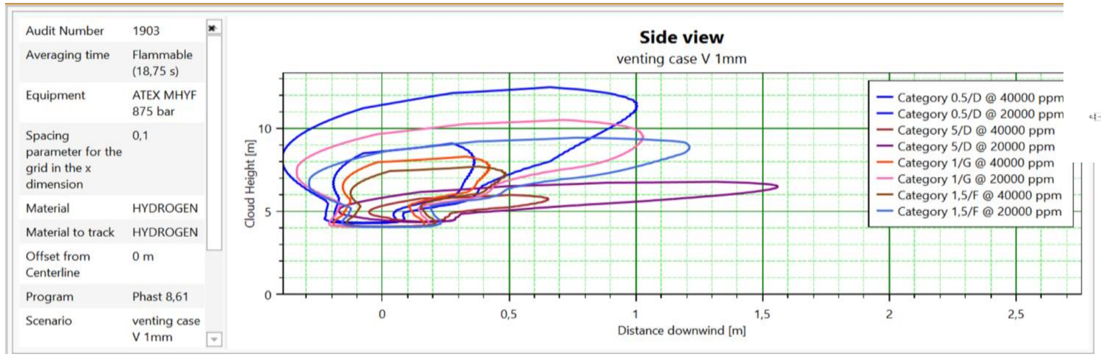
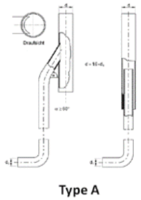
Constant release – horizontal release



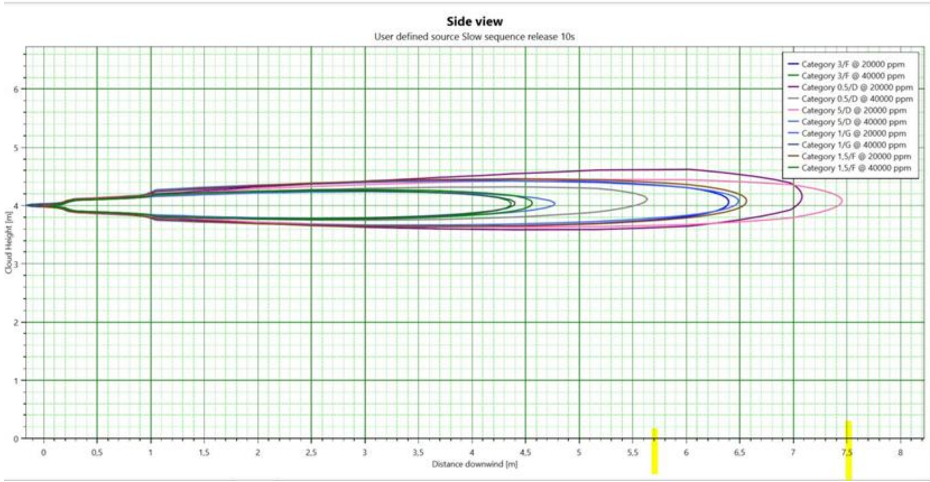


Constant release – vertical release





Limited volume – horizontal release



Conclusions

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Internal zones

- For our case study of a naturally-ventilated dispenser, a minimum of **zone 1 with natural ventilation inside the dispenser** was determined.
- For each application, an assessment of ventilation and release rate should be performed considering a different type of zone.
- **Non-hazardous zone classification inside dispenser is not possible** (for the theoretical work on this WP) due to high pressure inside dispenser. **Zone 2 could be reached with mechanical ventilation at high flow rate** (this will need to be demonstrable)
- Hole size selection and justification for H2 technologies require **further research and analysis**.
- **Small hole sizes 0.025 mm^2 (0.18 mm) for H_2 fittings need to be justified** and used with caution. It is recommended that at the very minimum, **pressure integrity checks in the dispenser are performed regularly,** including all the fittings that can potentially generate a release.

External zones

- The extent of a flammable cloud is recommended to be calculated as the distance to reach a **concentration of 50% LFL H_2** in order to consider uncertainties with respect to dispersion and ignition. Modelling gives an average value of concentration over time and there is variability in the instantaneous concentration of the gas.
- For hazardous area classification around dispenser venting, it is recommended to evaluate the restricted volume inside the dispenser which can be vented and to take into consideration restriction orifice to evaluate
- The extent of the **zone is directly dependant on the expected hole size** generating such releases. For instance, a hole size of 0.025 mm^2 would result in distances between 1.5 m to 2 m depending on the dispersion tool used. However, if the type of elements, installation and operation would not allow the justification of a 0.025 mm^2 hole, but a larger hole size is more representative instead, for example 0.1 mm^2, the estimated hazard extent could increase to approximately 4 m using Phast and 6.5 m if using Quadvent.

Clean Hydrogen Partnership

Content

Time	Title	Speaker
14.00 - 14.10	About MultHyFuel	Hydrogen Europe
14.10 - 14.20	Permitting Requirements in Europe	Hydrogen Europe
14.20 - 14.25	MultHyFuel Final Deliverable D3.7/8: Developing Good Practice Guidelines in Project MultHyFuel: Structure and Terms of Reference/ Caveats	HSE SD (Ju Lynne Saw)
14.25 - 14.40 14.40 - 15.10 15.10 - 15.25	Risk Assessment Approach: Methodology and Likelihoods Consequence Analysis •Experimental findings Hazardous Area Classification Example	INERIS (Sylvaine Pique) HSE SD (recording of Louise O'Sullivan) ITM Power (David Torrado)
15.25 - 15.40 15.40 - 15.50	**6.1 Recommendations and technical suggestions for further research to inform the development and/or update of Codes and Standards:** **•Dispenser design** **•Hazardous Area Classification** 6.2 Technical suggestions for further research and harmonisation of good practice	**ITM Power (Nick Hart)** **ITM Power (David Torrado)** INERIS (Sylvaine Pique)
15.50 - 16.00	Closing and Post project activities	Hydrogen Europe

Recommendations: Standardisation

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<u>ISO/TC 197: Hydrogen Technologies</u>

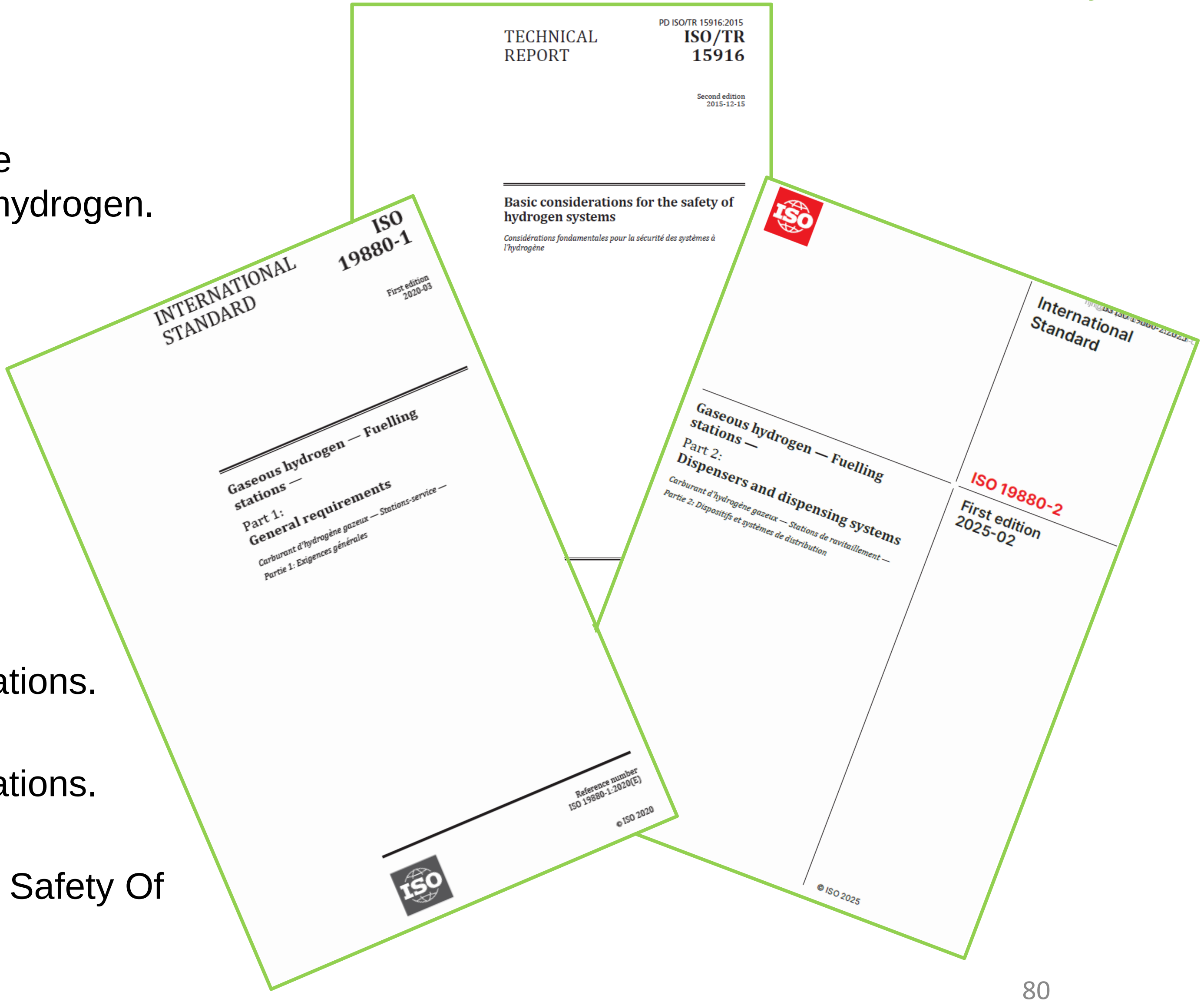
SCOPE
Standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen.

Secretariat: SCC (Standards Council of Canada)
Current Chair: Tetsufumi Ikeda (Japan)

- 22 published standards
- 27 standards under development
- 44 participating members
- 15 observing members

https://www.iso.org/committee/54560.html

- ISO 19880-1 - 2020 - Gaseous hydrogen. Fuelling stations. General requirements
- ISO 19880-2 - 2025 - Gaseous hydrogen. Fuelling stations. Dispensers and dispensing systems
- ISO TR 15916 - 2015 - Basic Considerations For The Safety Of Hydrogen Systems



Clean Hydrogen Partnership

Recommendations: Standardisation

ISO/TC 197: Hydrogen Technologies

Revision underway:

- ISO 19880-1 - Gaseous hydrogen. Fuelling stations. General requirements *(Working Group TBC)*
- ISO TS 15916 - Basic Considerations For The Safety Of Hydrogen Systems *(Working Group 29)*

Additionally:

CEN/CLC/JTC 6: Hydrogen In Energy Systems

Working Group 3 developing future Technical Specification for hydrogen systems in enclosed spaces.

Recommendations: Standardisation

IEC/TC 31: Equipment For Explosive Atmospheres

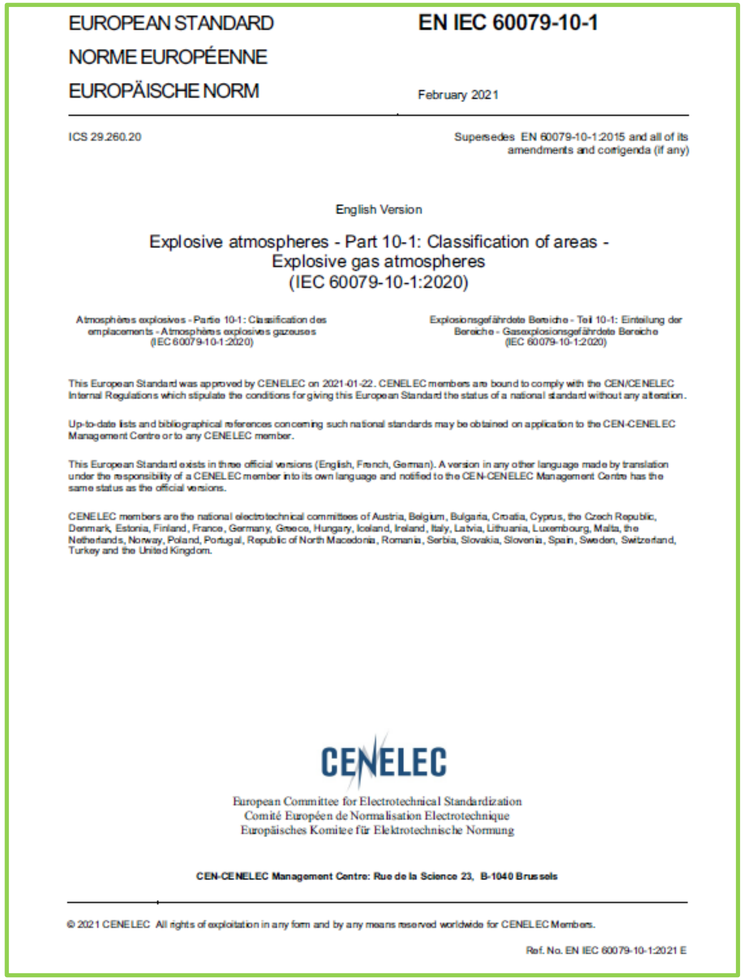
To prepare and maintain international standards relating to equipment for use where there is a hazard due to the possible presence of explosive atmospheres of gases, vapours, mists or combustible dusts.

IEC/TC 31/SC 31 J: Hydrogen Technologies

To prepare and maintain international standards relating to the use of equipment including area classification, the selection and installation, inspection and maintenance, repair, overhaul and reclamation of equipment where there is a hazard due to the possible presence of explosive atmospheres of gases, vapours, mists or combustible dusts

https://www.iec.ch/dyn/www/f?p=103:7:::::FSP_ORG_ID:1333

- IEC 60079-10-1 - 2020 - Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres
- *Note: published in Europe as EN IEC 60079-10-1 - 2021*



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN IEC 60079-10-1

February 2021

ICS 29.260.20

Supersedes EN 60079-10-1:2015 and all of its amendments and corrigenda (if any)

English Version

Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres (IEC 60079-10-1:2020)

Atmosphères explosives - Partie 10-1: Classification des emplacements - Atmosphères explosives gazeuses (IEC 60079-10-1:2020)

Explosionsgefährdete Bereiche - Teil 10-1: Einteilung der Bereiche - Gasexplosionsgefährdete Bereiche (IEC 60079-10-1:2020)

This European Standard was approved by CENELEC on 2021-01-22. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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

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Ref. No. EN IEC 60079-10-1:2021 E

Recommendations: Dispenser (6.1.1)

MultHyFuel

Recommendations for dispensers

- Dispenser design should incorporate openings/ apertures for natural ventilation and wind-reinforced ventilation to reduce the potential hydrogen accumulation in case of a loss of containment;

- Horizontal ventilation apertures in the upper areas of the dispenser (depending on geometry of the dispenser) are more efficient to benefit from wind, whatever the wind orientation;

- H_2 detection inside the dispenser with associated emergency protocol and actuation in case of detection and alarm at a suitable preset setpoint;

- Explosion panels (see next slides)

- Early detection of releases from distributing hose and efficient associated emergency protocol(s) (requirement: maximum detection and reaction time can vary between 2 s and 5 s depending on local regulations);

- Review installation of restriction orifice, excess flow valves (in the pipework upstream of the dispenser) or potential alternative measures to limit the flow rate in case of a large leak, but compatible with vehicle filling requirements;

Recommendations: Dispenser (6.1.1)

MultHyFuel

Recommendations for dispensers

- Use of breakaway coupling to isolate the system and limit hydrogen inventory release in case of drive-away;
- Use of an isolation valve within the dispenser that isolates the H_2 system and limits hydrogen inventory release in case of identified loss of containment or failure of the breakaway to engage;
- Installation of electrical equipment must follow the Hazardous Area Classification of the installation;
- Ensure grounding of H_2 equipment such as the dispenser nozzle.

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Recommendations: Dispenser (6.1.1)

MultHyFuel

Recommendations for dedicated explosion panels

- Should be built to one of the recognised Standards such as (BS EN 14994, 2007) or (NFPA 68, 2023), for e.g. a 1 m^3 dispenser housing as used in the experiment gives vent areas of 0.9 and 1.2 m^2 respectively;

- Whilst these offer guidance on a methodology for determining required venting panel sizes, it is recognised that standards can sometimes provide conservative results on the required vent area:
  - Other empirical models demonstrate that smaller vent areas could lead to the same reduced pressure.
  - Should designers wish to use these empirical standards, careful checks will need to be made to ensure that safety is not compromised;

- In the MultHyFuel experimental setup, there was a tall (2 m height), relatively thin (0.5 m width) dispenser with a weak panel of 0.5 m^2 located on the top (equal to the entire footprint) of the dispenser:
  - This is below that specified in the relevant standards, but extra venting was available through the natural ventilation apertures and the open bottom of the dispenser.
  - Moreover, the dispenser also experienced some plastic deformation - the standards specify a vent area such that no plastic deformations occur.
  - Designers should consider whether the appropriate level of safety is met, in the case of damage to the dispenser, for e.g., ensuring fragments are not generated.

Recommendations: Dispenser (6.1.1)

MultHyFuel

Recommendations for dedicated explosion panels

- If explosion vent panels are not sized to one of these standards or according to the test configuration, there should be reliable modelling or experimental testing to demonstrate their efficiency and suitability;

- A general principle is that dispensers should be as short as possible, however it should be taller than the average height of a person (so at least 2 m in height), and to allow for a suitably-sized explosion panel being installed above head height:
    - Ideally these would be orientated in an upwards direction.
    - The aspect ratio H/L/W for the studied mock-up dispenser, which was approximately 2 m / 1 m / 0.5 m, required the size of the explosion panel to be equal to the whole footprint of the dispenser (1 m × 0.5 m).
    - This vent size was considered, according to the experimental results, sufficient to mitigate the consequences of the potential explosion inside the dispenser for the current aspect ratio;

- Integration of a dispenser onto a forecourt should take into consideration parameters that may impact the sizing and efficiency of the explosion vent panels, e.g. obstructions facing, or near the vents, for instance, walls or canopy in the forecourt.

Recommendations: Canopy (6.1.1)

MultHyFuel

Recommendations for canopy design

Note: Canopy design was not a significant part of the work of MultHyFuel – the following are observations made following the work of the project

- Canopy structure should be designed in a way that avoids accumulation of any hydrogen release (e.g. inclined canopy roof; as well as sufficient distance between dispenser roof and canopy);

- Alternatively, an individual canopy per dispenser could be considered, so that any potential collapse is localised.

Recommendations: HAC (6.1.4)

MultHyFuel

- **Hazardous Area Classification (HAC) methodologies define the extent of releases to the lower flammability limit (LFL).** Due to uncertainties with respect to dispersion and ignition (modelling gives an average value of concentration over time and there is variability in the instantaneous concentration of the gas), it is recommended that designers consider the application of safety factor to the LFL

- Local conditions of wind and temperature need to be taken into consideration because they have a significant influence on HAC, specifically for the zoning of enclosures

- Hole size selection and justification for H2 technologies require **further research and analysis**.

- **Small hole sizes 0.025 mm^2 (0.18 mm) for H_2 fittings need to be justified** and used with caution. It is recommended that at the very minimum, **pressure integrity checks in the dispenser are performed regularly,** including all the fittings that can potentially generate a release.

- Within such hazardous zones, **operators shall ensure control of ignition sources** as per regulations; and implement restrictions/ safety procedures and protocol around the dispenser within these zones in order to limit the presence of ignition sources.

- For each application**, an assessment of ventilation and release rate should be performed to consider a different type of zone**. For the example analysed in this work, a Zone 1 with natural ventilation was obtained.

Recommendations HAC (6.1.4)

MultHyFuel

External zones

- For hazardous area classification around dispenser venting, it is recommended to evaluate the restricted volume inside the dispenser which can be vented and to take into consideration restriction orifice to evaluate

- The estimated extent of the zone is directly dependent on the assumed hole size generating such releases. For instance, for hole sizes of 0.025 mm^2, a hazardous zone ranging between 1.5 m to 2 m, depending on the dispersion tool used, would be obtained. However, if the type of elements, installation and operation would not allow the justification of a 0.025 mm^2 hole, but a larger hole size is more representative instead, for example 0.1 mm^2, the estimated hazard extent could increase to approximately 4 m using Phast and 6.5 m if using Quadvent.

Content

Time	Title	Speaker
14.00 - 14.10	About MultHyFuel	Hydrogen Europe
14.10 - 14.20	Permitting Requirements in Europe	Hydrogen Europe
14.20 - 14.25	MultHyFuel Final Deliverable D3.7/8: Developing Good Practice Guidelines in Project MultHyFuel: Structure and Terms of Reference/ Caveats	HSE SD (Ju Lynne Saw)
14.25 - 14.40 14.40 - 15.10 15.10 - 15.25	Risk Assessment Approach: Methodology and Likelihoods Consequence Analysis •Experimental findings Hazardous Area Classification Example	INERIS (Sylvaine Pique) HSE SD (recording of Louise O'Sullivan) ITM Power (David Torrado)
15.25 - 15.40 **15.40 - 15.50**	6.1 Recommendations and technical suggestions for further research to inform the development and/or update of Codes and Standards: •Dispenser design •Hazardous Area Classification **6.2 Technical suggestions for further research and harmonisation of good practice**	ITM Power (Nick Hart) ITM Power (David Torrado) **INERIS (Sylvaine Pique)**
15.50 - 16.00	Closing and Post project activities	Hydrogen Europe

Final Workshop
MultHyFuel - 2025

Technical suggestions for further research and harmonization of good practice

17/06/2025

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe research.

1. Introduction

- The pre-normative research carried out within the confines of the MultHyFuel project led to the identification of **some gaps in knowledge** that may need to be filled in order to inform codes and standards.

- There also remains some separate general knowledge gaps which were **excluded from the project scope**, which need consideration and investigation – some of which are already in progress by other projects (including, but not limited to HyIndoor, HyResponse, HyResponder, PRESLHY, SH2IFT, ELVHYS, (IEA Hydrogen TCP Task 43, 2024), (ISO/TC 197, 1990) including WG 24, 29, 35 and 39, CEN/CNL/ JTC 6/WG3, H2FIRST

Liquid Hydrogen

MultHyFuel

- **No data is available** from the MultHyFuel project to provide technical **recommendations on the modelling of liquid hydrogen releases**. Nevertheless, other projects such as PRESLHY, SH2IFT, MarHySafe (Phase I and II), ELVHYS can be consulted to more specifically address liquid hydrogen scenarios, which are not in the scope of the MultHyFuel project

Dispenser Design

- Current work is based on dispenser design as per (ISO 19880-2, 2025). For **new dispenser designs/specific considerations**, (e.g. from production up to distribution integrated within the dispenser housing) **a dedicated assessment** should be carried out by designers, engineers and manufacturers;

- **For specific/atypical designs of dispenser**, the **design of venting explosion panels** should be investigated further on a case-by-case basis; and

- **For specific/atypical designs of dispenser**, the impact of (higher) **internal obstruction level in the upper segment of the dispenser**(compared to that in MultHyFuel) may be investigated in terms of severity of the explosion in case of ignition.

Safety on the forecourt

MultHyFuel

- **Risk assessments of the installation** should consider detailed information from **suppliers of breakaways** (failure rates and modes) and **analyse potential human** factors to ensure risk is kept as low as reasonably practicable.

- In addition, there needs to be further research into the **emergency shutdown systems on multifuel forecourts.** For instance, a **combination of detection and shut-off valve actioning** could be investigated, with ignition of the released H2, taking into account the response time of the system; both in the dispenser (confined case) and on the forecourt (free field case).

Modelling approaches

MultHyFuel

Further investigation into existing modelling approaches may require additional experimental data.

- ❑ Address **the assumptions and limitations of the existing simple analytical models** and provide recommendations where numerical simulation brings added value to inform risk assessment methodology and assumptions; and

- ❑ **Carry out more detailed investigations** (experimental and numerical modelling) into complex scenarios, e.g. domino effects between different fuels other than hydrogen, taking into account realistic characteristics of multifuel stations

Interaction between H2 and other fuels

Investigation into the interaction between hydrogen and the other conventional fuels within a single dispenser/ compressor unit should be carried out:

- ❑ Integration of H2 within the same dispenser as the other conventional fuels, and the **necessary prevention and mitigation barriers**; taking into account potential **domino effects**(including flame acceleration mechanism and effects, for a single dispenser housing all types of fuels)

Further attention

The work conducted within the MultHyFuel project has identified several specific areas that would benefit from further attention and exploration by relevant regulatory, codes, and standards (RCS) bodies and organisations:

Good practice could be presented via an example multifuel HRS model(s) with ***design layout recommendations that minimise fire and explosion risks in compliance with national regulations*** *to protect people. e.g. reduction of leak points, hierarchy of controls (i.e. prioritising preventative and engineering controls over mitigation), promoting installations that are highly ventilated to prevent H2 accumulation, inspection of installations, etc..*

Suggestions for engagement between national regulators and relevant stakeholders:

MultHyFuel

- Harmonisation of **scenarios, harm criteria thresholds; and leakage sizes** for the definition of **safety distances** for multifuel refueling stations;

- **Review procedural control measures** to maintain exposure to members of the public to a minimum, in line with standards and guidance.

- The **Lower Explosive Limit (LEL)** (with relevant safety factors) could serve as a complementary—or even primary—basis for **defining hazardous zones**. Using the LEL as a **reference for hazard distance** aligns with a **preventive safety philosophy** and may help address situations where an **ignition source could be present outside the visible flame envelope**, but still within a flammable atmosphere. This approach could offer an **additional layer of conservatism and robustness to risk assessments**, particularly in complex urban or confined environments where even small flame flashes or overpressures can have significant safety implications.

Experimental research:

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Modelling and Hazardous Area Classification

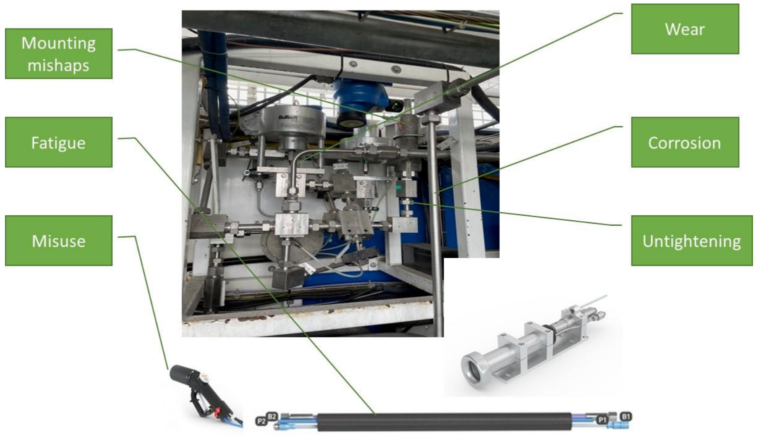
- **Expanding validation of leakage rates** for foreseeable sources through **experimental data and operational experience**; and

- **Review Hazardous Area Classification methodology** approaches to consider the specific characteristics of hydrogen technologies, including realistic release scenarios (hole size and momentum) and the dispersion characteristics.

Likelihoods

- ❑ More operational data is needed for **the validation and improvement of the AFS method developed** within MultHyFuel project; and

- ❑ **Review of variables affecting the probability of ignition of hydrogen** to inform risk assessments.



Safety barriers:

- Developing **inherently safe designs** for multifuel dispensers;
- **Testing the effectiveness** of various safety barriers (e.g. the detection-to-response time of the full "stop-leak" chain including detection and required actions to stop the leakage (e.g. isolation, valve actuation) to **ensure satisfactory mitigation response time**;
- **Determining the Confidence Level or SIL requirements** for safety barriers to reduce the probability of hazardous scenarios,
- Explore **additional procedural controls and maintenance** to prevent or reduce **potential static accumulation**, for example due to the involvement of members of the public in the refuelling operation;
- Developing **ultra-rapid hazard detection and isolation devices**, for e.g. acoustic detection. etc.
- Assessing the use of **fire and/or blast walls** as **mitigation measures for the station backyard.** Clear understanding from station designers on when and where to install fire and/or blast walls to avoid counter mitigation effects, e.g. the increase in the degree of confinement of a potential blast, leading *to* higher overpressures

Inherently Safe design

- Exploring the **feasibility of a single dispenser** capable of handling all fuel types, including hydrogen;

- Investigating **different canopy designs for multifuel HRS facilities**;

- Adhere to the **principles of inherent safety for the design of the hydrogen refuelling station and forecourt**, i.e. minimisation of inventory, minimisation of operator-based tasks, eliminate opportunities for error, etc.

Material compatibility and maintenance

- Examining **material compatibility and potential degradation effects** in hydrogen service, including piping, joints, seals, and other components,

- **Enhancing cleaning procedures for hydrogen systems**; and

- **Definition of maintenance regimes**, including periodic leak test and inspection procedures.

Organisational measures and training:

- **Establishing good practice** on **organisational management**, including Management of Change (MOC) and standardised operating procedures, to limit passenger presence near dispensers, including regular training of personnel;

- **HRS operators** to develop comprehensive user **training programs** for station operatives maintenance staff, to raise awareness of hydrogen-related risks;

- **Competence management** and **improvement of safety culture** of personnel involved in the **maintenance and assembly of HRS**.

Risk considerations in the backyard for multifuel Stations:

MultHyFuel

- ❑ **Detailed study of risks associated with all the equipment** (permanent bulk, as well as temporary mobile storage, compressor and process equipment) for different fuels including conventional and considering the potential domino effects;

- ❑ **Careful consideration of the siting of multifuel refuelling stations is of paramount importance.**

Conclude:

These considerations emphasise the importance of thorough, multidisciplinary efforts to advance the safety, reliability, and efficiency of multifuel hydrogen refueling stations, ensuring they meet both current and future demands.

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15.50 - 16.00	**Closing and Post project activities**	**Hydrogen Europe**

Clean Hydrogen Partnership

MultHyFuel

Post Project Activities

- Website (deliverables and recordings)
- Contact emails (**Q&A until July 31st 2025**)
  - info@multhyfuel.eu
  - d.durdevic@hydrogeneurope.eu
- Letter of Endorsement (**until July 17th, 2025**)

Post Project Activities – Letter of Endorsement

MultHyFuel

Letter of Endorsement

Added value of MultHyFuel results in the harmonisation of permitting rules and safety requirements throughout Europe

The signatories of this letter recognise the importance of developing evidence-based rules for the handling of hydrogen in multi-fuel refuelling stations and the relevance of MultHyFuel's results as a step towards this goal.

The ultimate goal of MultHyFuel is to develop guidelines for the implementation of HRS in multifunctional contexts based on practical, theoretical and experimental data as well as on the active and continuous engagement of key stakeholders.

All throughout the project, methodology and preliminary results were shared with relevant stakeholders, both through the organisation of dedicated workshops and bilateral exchanges with HRS operators, manufacturers and public authorities. This communication allowed these stakeholders to provide their feedback and maximise the results' impact.

The signatories of this letter have followed the communication initiatives organised by the Consortium and are now aware of the existence of evidence-based guidelines created within the project. These guidelines focus on the forecourt of the refueling stations and include, among others, recommendations for prescribed safety distances and risk assessment methodologies (to be adjusted once the deliverable is complete). Should there be the creation or revision of a legal framework within their country, the signatories know enough context around the results presented in D3.7 – (Name of the deliverable) to consider it a valuable source of information.

The signatories will strive for the adoption of common rules for the risk assessment and permitting of hydrogen refuelling stations in multi-fuel environment, following the outputs of the MultHyFuel project.

Moreover, through this endorsement, the signatories reaffirm their shared responsibility to enable the sustainable and safe growth of hydrogen refuelling infrastructure, aligned with the goals of the European Green Deal and the Hydrogen Strategy for a climate-neutral Europe.

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MultHyFuel

Signed:

____

[Stakeholder Organization]

____

[Signatory Position / Title]

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[Signature and stamp]

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[Date]

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Thank you for your attention!

info@multhyfuel.eu

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This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101006794. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

Clean Hydrogen Partnership