Clean Hydrogen Partnership

European Hydrogen Safety Panel (EHSP)
Clean Hydrogen JU Webinar "Computational Fluid Dynamics (CFD) for hydrogen safety analysis “, 07th December 2022

CFD modelling for assessment of effectiveness of mitigation measures: Sensor placement, blast/fire-walls, water spray etc

Pratap Sathiah

Member of European Hydrogen Safety Panel (EHSP)

EUROPEAN PARTNERSHIP

Clean Hydrogen Partnership

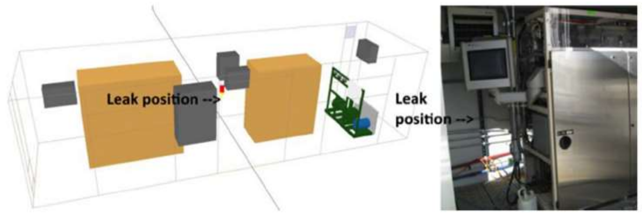
Presentation outline

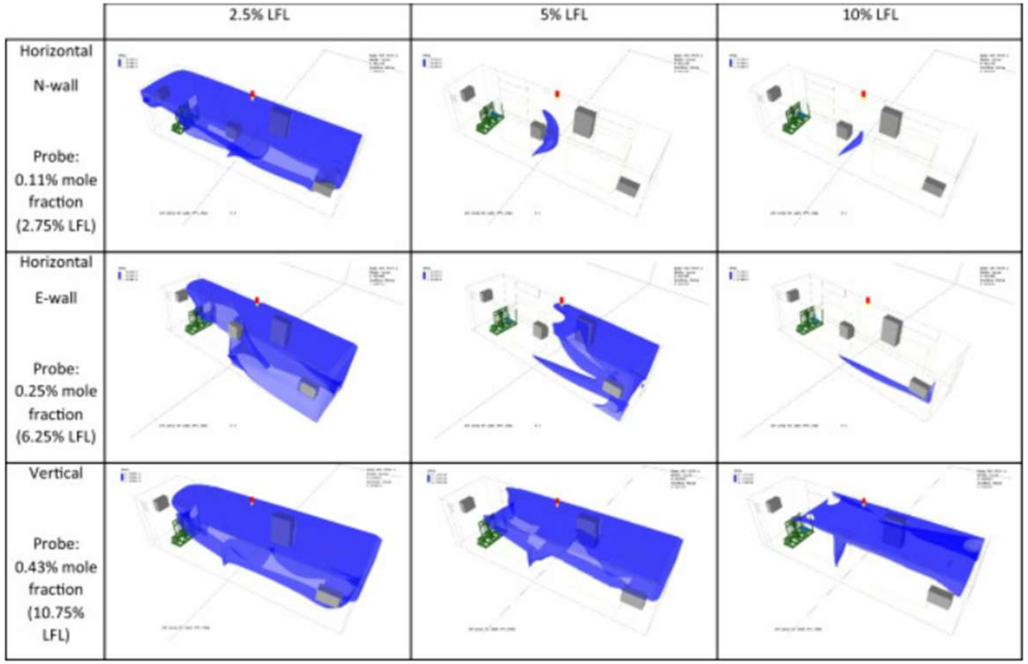
- CFD has also been used for the design of mitigation systems:
- Sensor placement and optimization – *faster detection, thereby limiting significant consequences*
- Design of firewalls - *A firewall is a passive structure often used in* ***hydrogen refuelling stations*** *to prevent personnel/objects from* ***fire and associated thermal radiation***.
- Design of blast walls - *A blast wall is simply a barrier which is used to protect the vulnerable structure and its occupants from* ***explosion overpressure, fire and debris.***
- Design of water spray for mitigation of dispersion - *Fine mist and water droplets produced from the water sprinkler system reduce* ***the flammability of the mixture*** *by promoting* ***mixing/dilution.***
- Design of PARS for explosion prevention - *Passive auto-catalytic recombiners (PAR)s are used to remove* ***hydrogen*** *in case of unintentional release of hydrogen. It* ***catalytically combines hydrogen with oxygen*** *in the air to form* ***water vapour****. It is used in the nuclear industries to* ***avoid the build-up*** *of the hydrogen-air flammable mixture.*

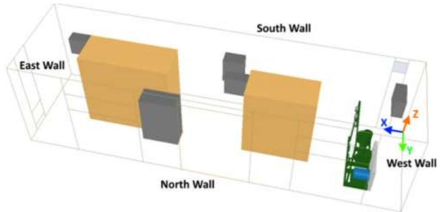
Co-funded by the European Union

CFD modelling for sensor placement/optimization for indoor releases

- CFD modelling of hydrogen dispersion was performed to develop **guidance for optimal sensor placement** that will allow earlier detection at **lower levels of incipient** leaks, thereby limiting significant consequences.
- Based on the **hydrogen concentration** distribution **sensor locations** were identified to be at the **top** of the enclosures.







Cloud contour at 2.5% LFL, 5% LFL and 10% LFL, 540 s after the onset of the leak for three cases a) horizontal release directed toward the North wall, b) horizontal release directed toward the East wall and c) vertical release directed toward the ceiling. Mole fraction and corresponding LFL values at the probe location (x= 4.1 m, y = 1.7 m and z = 2.2 m) included.

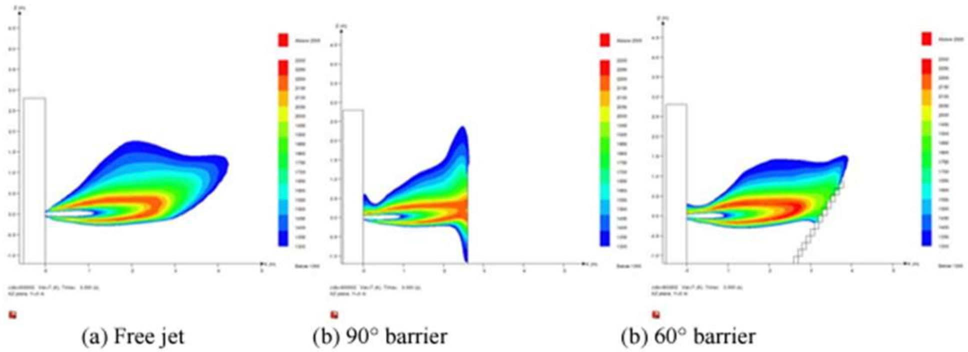
Andrei V. Tchouvelev et al., Development of risk mitigation guidance for sensor placement inside mechanically ventilated enclosures – Phase 1, International Journal of Hydrogen Energy, Volume 46, Issue 23, 2021, Pages 12439-12454, ISSN 0360-3199

Co-funded by the European Union

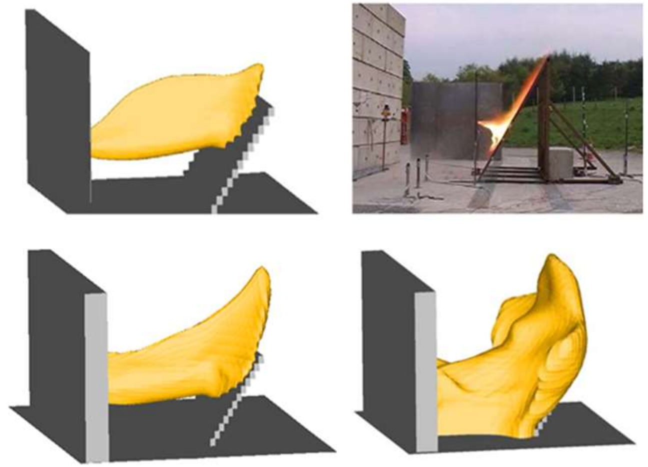
CFD modelling for design of firewalls for mitigation of fire

- A CFD simulation was carried out to assess the effectiveness of the **firewall**.
- The simulations were able to reproduce the **total heat flux** generated for various firewall configurations and orifice diameters.
- CFD-based tools can be used for the design of firewalls e.g**. height, thickness and orientation** etc.

Photos of the release location and vertical wall (left) and 60° barrier (right) also shown in the resulting jet fire images



Temperature plot to show effect of barrier for jet with diameter 3.2 mm



1300 K contour for 3.2 mm (2.3 s, upper left), 3.2 mm experiment (just after ignition, upper right), 6.4 mm (2.3 s, lower left) and 9.5 mm (1.4 s, lower right), with 60° barrier

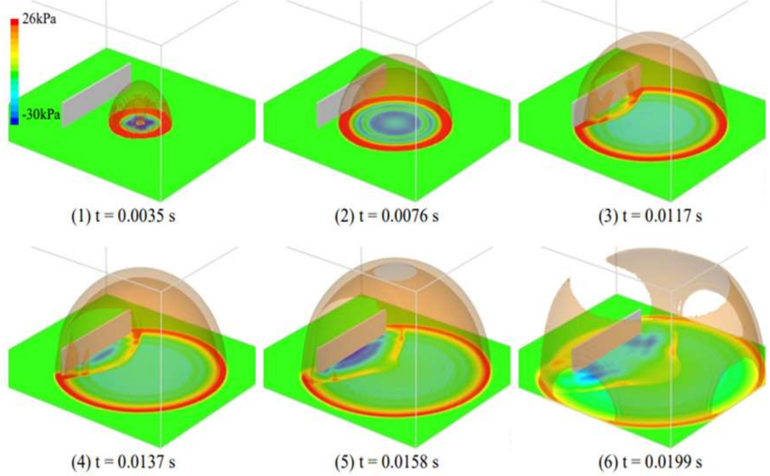
Deiveegan Muthusamy, Olav R. Hansen, Prankul Middha, Mark Royle and Deborah Willoughby, Modelling of hydrogen jet fires using CFD, International Conference of Hydrogen Safety, 2011, San Francisco, USA

Co-funded by the European Union

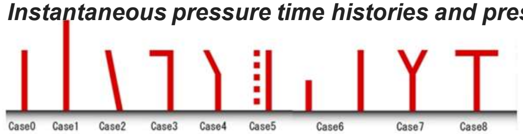
Clean Hydrogen Partnership

CFD modelling for design of blast walls for explosion mitigations

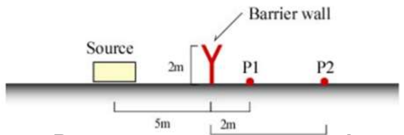
- A CFD simulation for this explosion was also carried out to assess the effectiveness of the **blast wall**.
- Parametric CFD simulations were conducted to find more **effective shapes** for **barrier walls** to mitigate blast effects.
- T-shape and Y-shape walls are **more effective** in mitigating blast overpressure because of the **wave diffraction**.



Instantaneous pressure time histories and pressure iso-surfaces at various times.



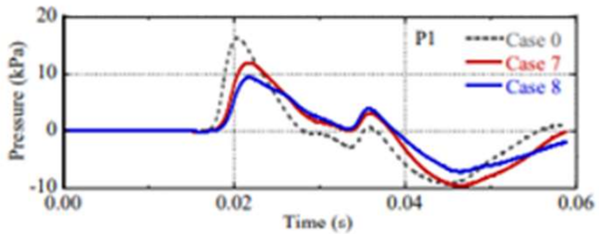
Analysed cross-sections of various barrier wall shapes.



Pressure measurement points.

case	wall shape	P1/P1(no wall)	P2/P2(no wall)	P1/P1(case0)	P2/P2(case0)
Case5		0.30	0.58	0.96	0.96
Case6		0.27	0.52	0.85	0.86
Case7	Y	0.23	0.52	0.74	0.86
Case8	T	0.18	0.48	0.58	0.80

The non-dimensional maximum value of the blast pressure for Case 5 to Case 8.



Blast pressure time histories at points P1.

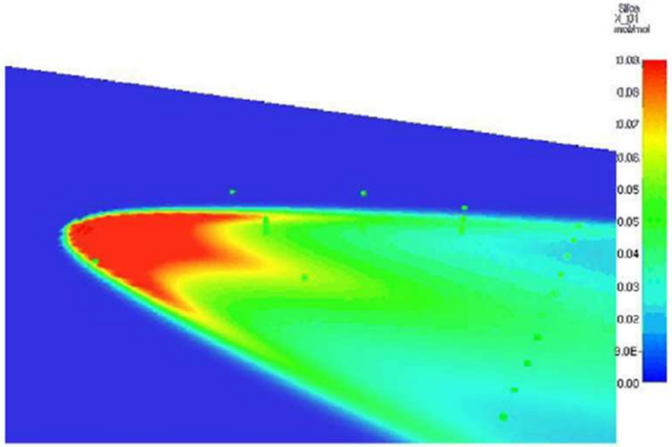
EUROPEAN PARTNERSHIP

Numerical simulations of hydrogen explosions for blast mitigation T. Nozu; R. Tanaka; T. Ogawa; K. Hibi; Y. Sakai, International Conference of Hydrogen Safety, 2005, Pisa, Italy.

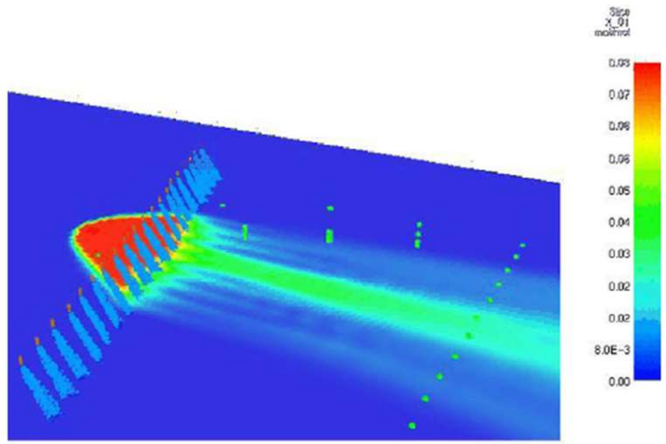
Co-funded by the European Union

CFD modelling of effects of water spray mitigation on dispersion

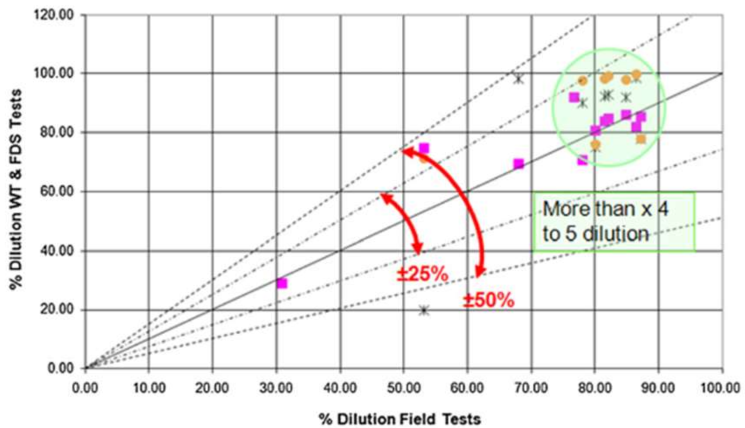
- CFD simulations are performed to reproduce the **transport** and **dispersion behaviour** of water spray/curtain on the **dense gases**.
- Modeling demonstrated the ability of a water-spray curtain to **dilute plume concentrations** by enhanced **entrainment** of the surrounding ambient air.
- **Effective dilution** directly downwind of the water spray curtain was determined to be a **factor** of **4–5.**



No spray configuration



With spray configuration



Percent Dilution (PD): CFD and Wind Tunnel data plotted versus Field values

x CFD case - 1

CFD Data - 2

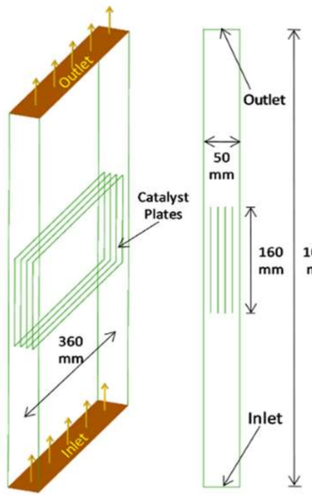
$$PD=\frac{C_{NS}-C_S}{C_{NS}}$$

N. Meroney, CFD modelling of water spray interaction with dense gas plumes, Atmospheric Environment, Volume 54, 2012, Pages 706-713, SSN 1352-2310.

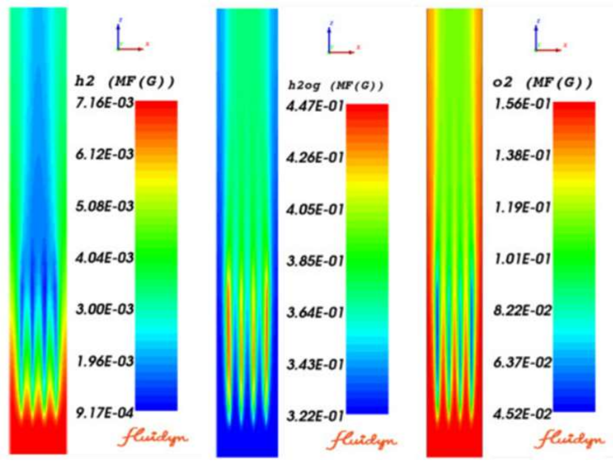
Clean Hydrogen Partnership

CFD modelling for design of PARS for explosion mitigation

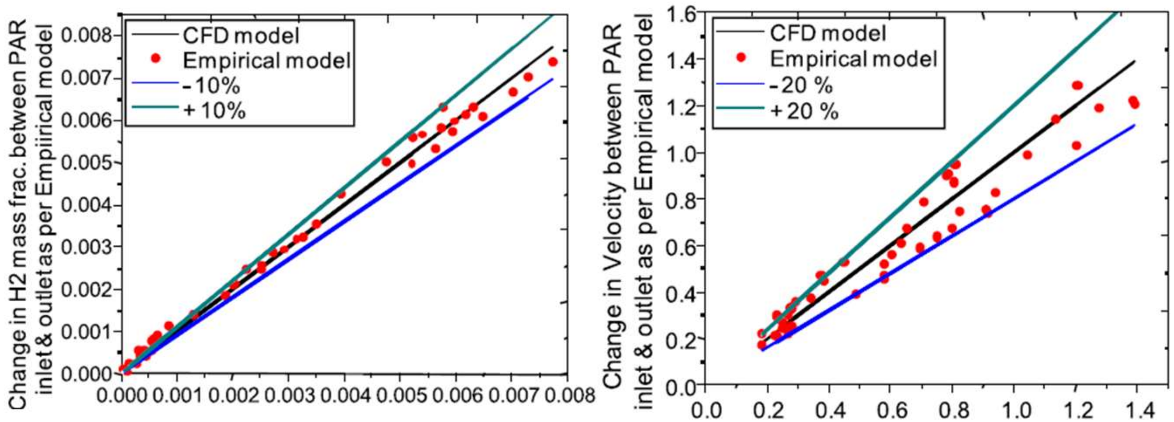
- It is well known that PARS is effective for **the removal of hydrogen** in the case of **unintentional release** of hydrogen in a containment/enclosure
- Full-scale three-dimensional recombiner detailed CFD model for simulating PAR performance in reactor containment is **computationally extensive**.
- The use of a **lumped model** for the PAR is an **alternative** which is computationally less extensive.
- CFD-based methodology is used to develop **empirical correlation** which predicts condition at the **recombiner outlet**.



Geometry with four plate arrangement: Computational domain



Contour plots for (a) hydrogen, (b) water vapor and (c) oxygen in terms of their respective mass fractions



Comparison of empirical model to CFD model for H2 mass fraction and change in velocity

Vikram Shukla et al. , Application of CFD model for passive autocatalytic recombiners to formulate an empirical correlation for integral containment analysis, Nuclear Engineering and Technology, Volume 54, Issue 11, 2022, Pages 4159-4169.

Co-funded by the European Union

Clean Hydrogen Partnership

Thank you

Pratap Sathiah
European Hydrogen Safety Panel
EHSP@clean-hydrogen.europa.eu

For further information
pratap.sathiah@airbus.com

Co-funded by the European Union