Fuel cells and hydrogen
Joint undertaking

HyIndoor
(Contract number 278534)

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New Energy World JU
fuel cells & hydrogen for sustainability

Programme Review Day 2013 – Brussels, 11&12 November 2013

Project overview

- Pre-normative research on safe indoor use of fuel cells and hydrogen systems
- 3 years (Jan 2012 – Dec 2014)
- 3.6 M€ budget – 1.5 M€ FCH contribution
- Partnership: Industry, FC and Gas companies, Testing laboratories, Research Institutes, Academia, Leading actors in RCS development, innovation & project management consultancy

AIR LIQUIDE HYGEAR CCS GLOBAL European Commission cea

HEALTH & SAFETY LABORATORY KIT University of ULSTER LGi CONSULTING

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Project achievements

1 - Project goals, milestones

- Develop the **knowledge base** required to be able to predict H2 use indoor and consequences in case of early or late ignition

Experimental and modeling results
Jan 2013 => June 2014

- Define **improved criteria for allowing hydrogen and FCsystems indoors**

Recommendations for RCS – Sept 2014

- Issue a **safety guideline**
  - Sizing of enclosure openings or forced ventilation in function of H2 release parameters
  - Sizing of the vent area for deflagration mitigation in relation to the accumulated inventory and obstruction in the enclosure

Guideline published on
www.hyindoor.eu – August. 2014

- **Disseminate the project outputs** through H2 safety community and industrials

Advanced Research Workshop
Sept 2013 – Bruxelles
Dissemination Workshop
Dec 2014 - TBD

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Project achievements
2 – Phenomena to be understood in confined space

DISPERSION

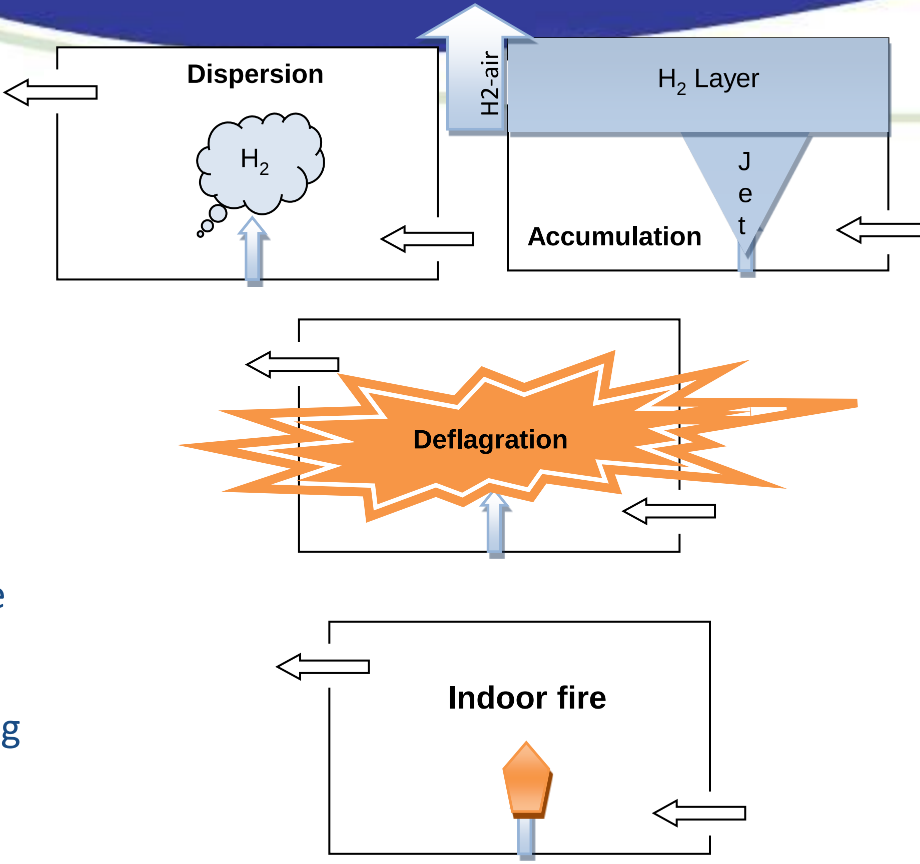
- Identify characteristic regimes of hydrogen dispersion
- Characterize and quantify the dynamics of the dispersion phenomena

DEFLAGRATION

- Hydrogen-air deflagrations including deflagrations of localised and stratified, turbulent and lean mixtures
- Inertial vent covers

JET FIRE

- Specific hazards for initial unsteady stage of fire development
- Self-extinction of enclosure fire, re-ignition phenomena and deflagration potential following extinction
- Under-ventilated and well-ventilated fires and associated thermal effects and hazards to life and property



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Project Achievements
3-Safety objectives and project expected outcomes

- Description of the emergency scenarios, hazards and associated risks
- Definition of safety strategies and engineering solutions and their comparison with research results
- Preliminary calculations (assessment of H2 build-up and explosion consequences) based on well known analytical models, and in some cases well-established hypotheses Identification and classification of the main **knowledge gaps**
- Review and proposal for RCS development

On the basis of these conclusions,
research program was formulated, refined,

or slightly reoriented depending on a degree of criticality classification of the identified issues.

Photo credit: HyGEAR, Air Liquide

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Project achievements
4 – Experimental and modeling results
Dispersion

Analytical

- The difference between natural and passive ventilation identified (UU)

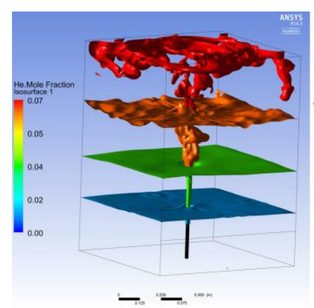
  A series of graphical calculation tools (nomograms) for hydrogen concentration evaluated against experimental results. Pressure peaking phenomena described. (UU)

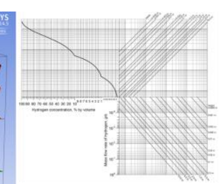
CFD

- Preliminary results indicate that RANS models underestimate maximum gas concentrations, while laminar simulations overestimate it. LES results, while computationally expensive, so far provide the best agreement with experiments.

Experimental

- Experimental research of jet dispersion in 5 x 2.5 x 2.5 m box (HSL). Wind influence study completed
- GAMELAN experimental study of helium release (CEA)

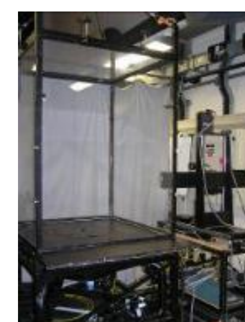




Nomogram for calculation of steady state uniform hydrogen concentration in the enclosure with one vent (above)

Helium molar fraction from Large Eddy Simulation of GAMELAN configuration (UU, left)

LES modelling of Helium molar fraction GAMELAN ($1m^3$) configuration (UU)



CEA Experimental Set up

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Project achievements
5 – Experimental and modeling results
Vented deflagration

Analytical

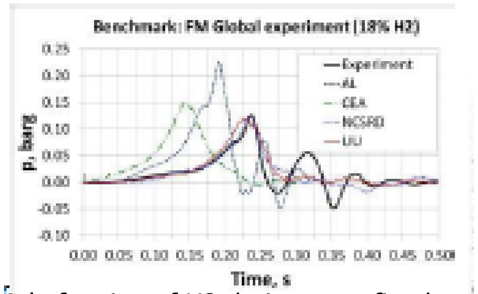
- Validation of vent-sizing correlation for uniform H_2-air mixture deflagration, development and validation of thermodynamic model for localised mixture deflagration overpressure, proposed adaptation of vent sizing correlation for localised H2-air mixture deflagration (UU)

CFD

- Adaptation of LES model, development and validation of Rayleigh-Taylor instability model, and benchmark of CFD tools against experimental data for lean H_2-air mixtures

Experimental

- Experimental data collected at KIT $1 m^3$ facility HSL $31 m^3$ vented enclosure facility prepared for full-scale vented deflagrations experiments



Mole fraction of H2 during a confined fire(UU)

HSL experimental set up

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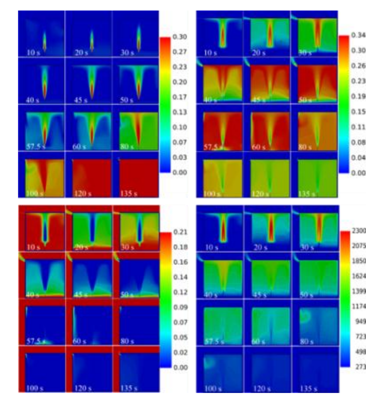
Project achievements
6 – Experimental and modeling results
Hydrogen Jet fire

Analytical

Development of a method to use the universal flame length correlation for assessment of flow restrictor (UU).

CFD

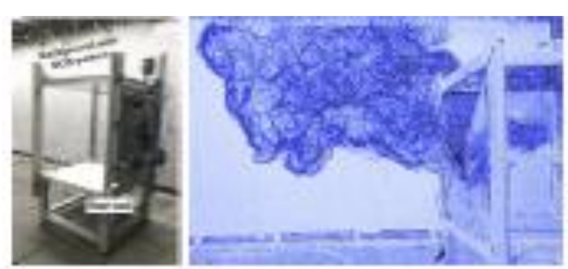
Parametric CFD studies of a fire in the enclosure with a single vent conducted for well-ventilated and under ventilated regimes for both upper and lower vent locations. Two modes of under-ventilated fires (external flame and self-extinction) identified (UU).



Mole fraction of H2 during a confined fire(UU)

Experimental

KIT and HSL Preparation for experimental tests.
Results expected for Q1/2014



KIT experimental setup

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Project achievements
Goals

- Finalisation of **numerical and modeling results, and sensors benchmar**k
- **Safety guideline** and **input to RCS** under construction
- **Advanced Research Workshop (ARW**) "Progress in safe indoor use of fuel cells and hydrogen systems" was held on September 12, 2013 in Brussels, Belgium (35 participants, 4 sessions with 17 presentations by leading researchers and industry representatives from across the globe)

- **Other dissemination activities:**

  24 publications published in professional journals or proceedings of international conferences, including 4 journal publications; 2 books and 2 book chapters

Alignment to MAIP
1 – prenormative research on safety

- Generic knowledge will be issued and will address the following objectives
  - Early markets
    - “ In order to pave the way for a widespread acceptance of fuel cells in early applications pre-normative research will aim to **develop methodologies and procedures** for **safe indoor use of fuel cells** […] and compatibility with electrical and building codes.”
  - Cross cutting issues
    - “Developing European and international standards that provide the technical requirements to achieve safety and build confidence as well as **guiding authorities and other stakeholders** in their application.”
  - Transport & Refuelling Infrastructure
    - “ Pre-normative research will complement the RTD in this application area. In particular […] safety of hydrogen **[material handling] vehicles especially in confined spaces**.”

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Cross-cutting issues
1 – RCS

- Translation of scientific results into international norms. Possible influence on:

Document #	Description	Active	Published
ISO/TR 15916	Basic considerations for the safety of hydrogen systems	√ Ed 2	
ISO/DIS 20100	Gaseous hydrogen — Fuelling stations (supersedes ISO/TS 20100)	√ Ed 1	
IEC/NP 62282-4-101	Fuel cell technologies – Part 4-101: Fuel cell systems for forklift applications – Safety	√ Ed 1	
IECCDV 62282-5-1	Fuel cell technologies - Part 5-1: Portable fuel cell power systems – Safety	√ Ed 2	
IEC 62282-3-100 :2012	Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety (Revision of IEC 62282-3-1)		√ Ed 1
IEC 62282-3-300:2012	Fuel cell technologies - Part 3-3: Stationary fuel cell power systems – Installation		√ Ed 1
IEC 60079-10-1	Explosive atmospheres – Part 10-1: Clarification of areas – Explosive gas atmospheres	√ Ed 1	√ Ed 2

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Recommendations towards the program

Potential hydrogen safety subjects could include the following topics:

- Flame acceleration in partially confined and obstructed areas
- Mechanical structure resistance exposed to explosion (internal or external) and coupling of structure and explosion regarding to external overpressure effects.
- Influence of obstruction on dispersion in natural ventilation
- Mechanical ventilation
- Hydrogen dispersion in large volume (transient approach)
- Development of focused education and training programmes to ensure that the progress in inherently safer use of hydrogen and fuel cells indoors includes latest HyIndoor project results and recommendations.

Thank you for your attention

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