PRESLHY WP4 - ignition

Kick-off meeting, 17th April 2018, KIT

Pre-normative REsearch for Safe use of Liquid HYdrogen

WP4 objectives

- To identify and understand the ignition risks associated with situations unique to liquid hydrogen releases, where factors of cryogenic temperatures are significant
  - ignition potential at reduced temperature in the vapour phase
  - electrostatic charging in liquefied/multiphase mixtures
  - energetic multiphase mixtures of hydrogen and oxygen
- To understand the impact of these particular circumstances

Key phenomena

- Electrostatic charge generation and build up associated with multi-phase releases/mixtures
- Evaluation and characterisation of processes that may lead to mixed H_2 and O_2
- Ignition of mixed solid/liquid/gas phase involving H_2 and O_2
- The susceptibility of H_2/O_2 mixtures to ignition by various means
- Flammability characteristics for low temperature
- Other ignition phenomena (spark, fire, catalytic materials, radiation, “diffusion ignition”…)

Deliverables and schedule

- D4.1 Theory and Analysis of Ignition with specific conditions related to cryogenic hydrogen (public report, month 18), Leader HSL, partners all.
- D4.2 Computational investigation of cryogenic hydrogen release and dispersion (public report, month 36), Leader HSL, partners all.
- D4.3 Experimental investigation of cryogenic hydrogen release and dispersion (public report, month 36), Leader HSL, partners all.
- D4.4 Summary of experiment series E4.1 results (confidential report, month 11), INERIS
- D4.5 Summary of experiment series E4.2 results (confidential report, month 29), PS
- D4.6 Summary of experiment series E4.3 results (confidential report, month 25), HSL
- D4.7 Summary of experiment series E4.4 results (confidential report, month 22), PS
- D4.8 Summary of experiment series E4.5 results (confidential report, month 30), HSL

		Month																																			
Partner	Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
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KIT/PS	E4.2																																				
HSL	E4.3																																				
KIT/PS	E4.4																																				
HSL	E4.5																																				

Task 4.1 – Theory and analysis

- The primary aim is then to understand scenarios that are unique to LH_2, which may not have been previously addressed and may introduce novel, previously unobserved and poorly understood pathways to ignition
- This will be done by first collecting and critically reviewing existing information in order to identify gaps in understanding of related physical phenomena and their control
- Secondly, this subtask will concentrate on proposing a clear roadmap for closing the identified gaps

Research priority workshop on hydrogen safety


European Commission

JRC CONFERENCE AND WORKSHOP REPORTS

Research Priority Workshop on Hydrogen Safety

26-27 September 2016
Petten, The Netherlands

Editors:
Dolci, Francesco (EC-JRC),
Jordan, Thomas (KIT),
Keller, Jay (ZCES, DOE) and
Moretto, Pietro (EC-JRC)

Authors:
Azkarate, Iñaki (Tecnalia),
Barthélémy, Hervé (Air Liquide),
Hooker, Phil (HSL),
Jordan, Thomas (KIT),
Keller, Jay (ZCES, DOE),
Markert, Frank (DTU),
Steen, Marc (EC-JRC) and
Tchouvelev, Andrei (AVT)

2018

hySafe

Joint Research Centre

EUR 29146 EN

"Spontaneous ignition of hydrogen air mixtures is not at all well understood"

- The following have been proposed explanations for the observed ignition:
  - Joule-Thomson heating (ruled out a 100 MPa release only increase the temperature by 53K not enough to reach the auto ignition temperature of ~858K)
  - Electrostatic discharge (discharge from charged particles)
  - Diffusion ignition (transient high-temperature shock waves)
  - Adiabatic compression (difficult to differentiate from diffusion ignition)
  - Contact with a hot surface
  - Catalytic reaction with materials present in the flow (iron oxide)

Research priority workshop on hydrogen safety

4.4 Gaps and Next Steps:

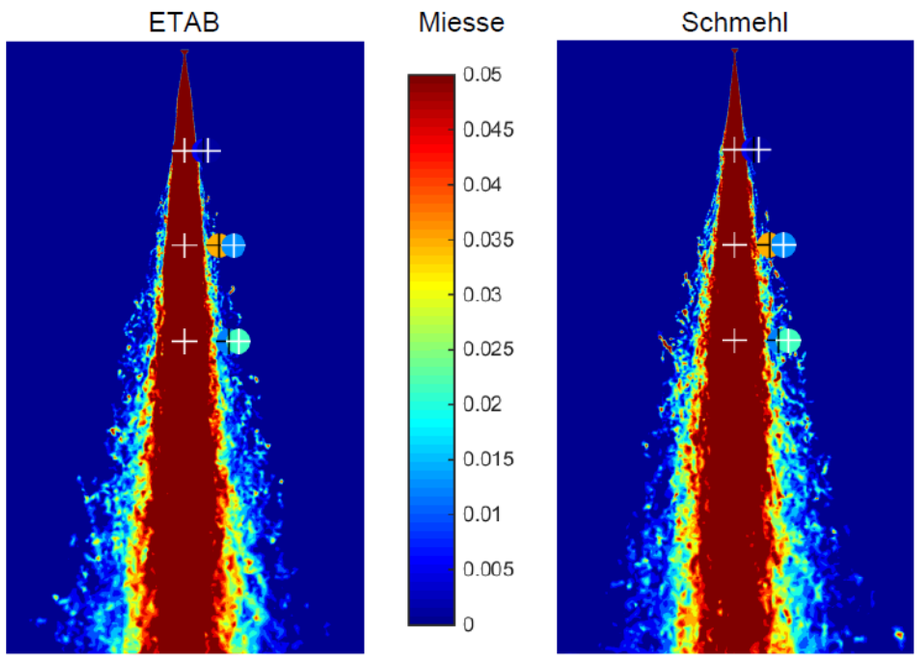
- Ignition -
  - Forced
    - Reduced order model for accurate prediction of flammable extent (FF)
    - Influence of hardware in the flow (igniter vs laser spark)
  - Spontaneous
    - Fundamental Mechanisms
    - Prediction

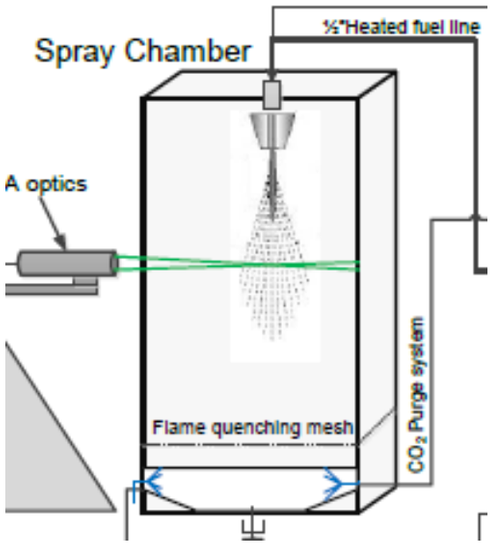
Task 4.2 – Simulations (UU)

- Relationships between the standard ignition parameters (Flammability domain, MIE,...) and the practical ignition sources will be established on the theoretical basis
  - Model spark ignition of cryogenic hydrogen-air mixtures with air accounting for chemical kinetics
  - Diffusion ignition simulations to understand the impact of enhanced density of cryogenic releases on the shock ignition process, and the trade off against increased difficulty of igniting cold H_2/air mixtures.
  - Studies to understand phenomena associated with cryogenic mixtures of H_2/O_2 and their formation/ ignition.

Simulations of ignitability – oil mists

- HSE research report RR1111 - CFD modelling of oil mists for area classification





Task 4.3 – Experiments

- E4.1 General ignition parameters (INERIS)
- E4.2 Electrostatic ignition in a cold jet (KIT)
- E4.3 Electrostatic ignition in a cold plume (HSL)
- E4.4 Ignition of a spill of LH_2 (KIT)
- E4.5 Ignition of H_2/condensed O_2 phase (HSL)

E4.1 General ignition parameters

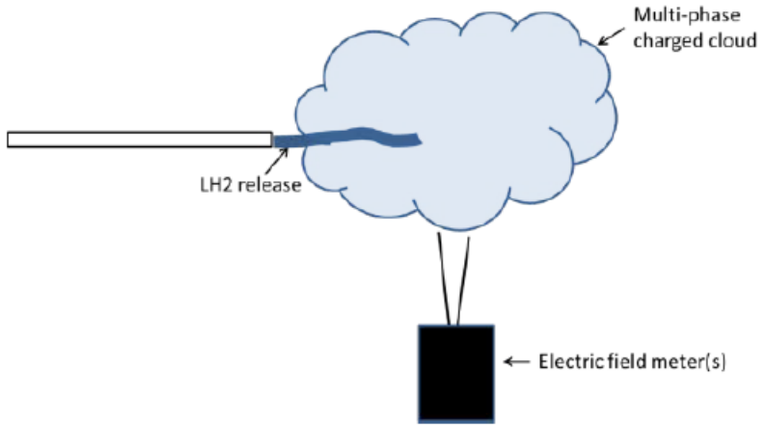
- Investigation of the standard ignition parameters as a function of temperature of mixtures, within the range -100 ^{o}C – 20 ^{o}C
  - MIE
  - Flammability domain
  - Laminar burning velocity

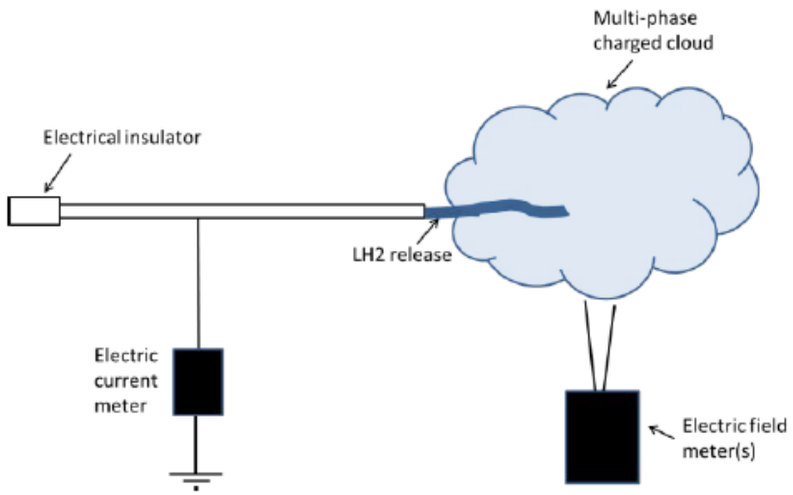
E4.2 Electrostatic ignition in a cold jet

- Investigation of the generation of electrostatic charge using Cold-Jet-Facility, varying:
  - Initial pressure
  - Initial temperature
  - Nozzle diameter

E4.3 Electrostatic ignition in a cold plume

- Electrostatic measurements on a plume, to estimate the average charge density and maximum potential of the cloud

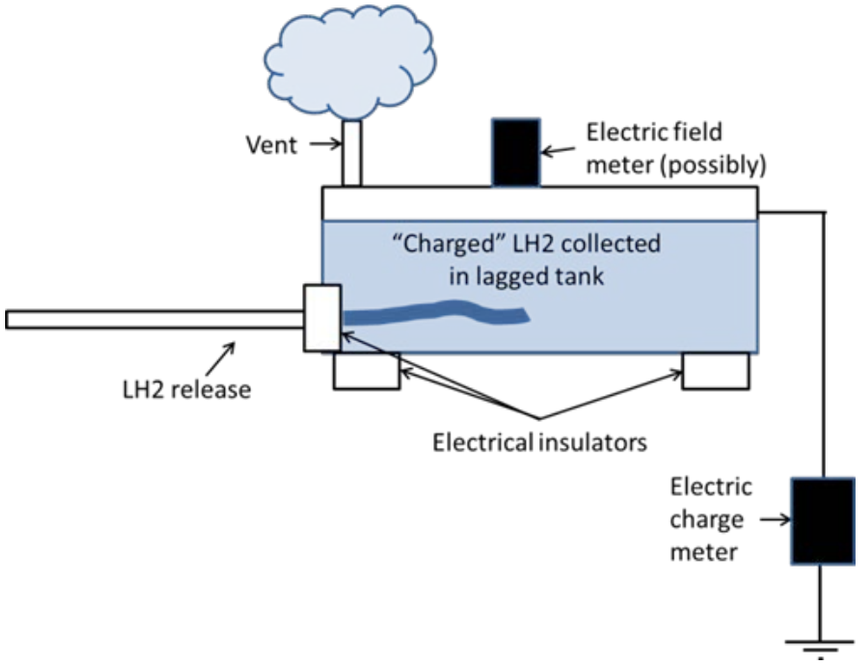




- To provide base level electrostatic measurements to draw practical implications from – i.e. comparison of propensity to ignite vs organics
- Possible variables:
  - Controlled: velocity, flow rate, change with time as pipe / surroundings cool
  - Uncontrolled: humidity

E4.3 Electrostatic ignition in a cold plume

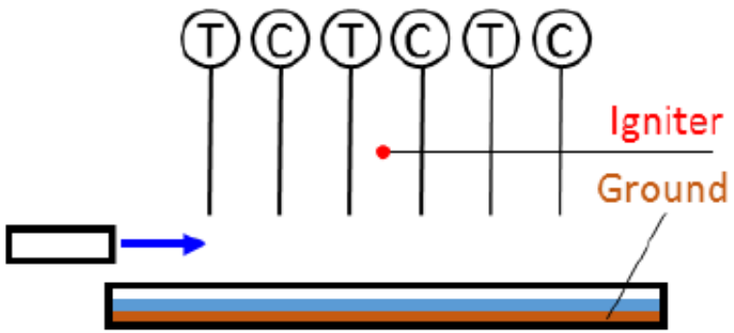
- Electrostatic measurements on pipeline, to estimate the charging current / charge density in bulk liquid flow



- To provide base level electrostatic measurements to draw practical implications from – i.e. comparison of propensity to ignite vs organics
- Possible variables:
  - Controlled: velocity, flow rate

E4.4 Ignition of a spill of LH_2

- 1 m^2 liquid pools
  - 3 ground materials
  - Initial temperature
  - Ignition position
  - Ignition energy
  - Ignition source
- Measurements
  - BOS imaging
  - Temperature
  - Concentration

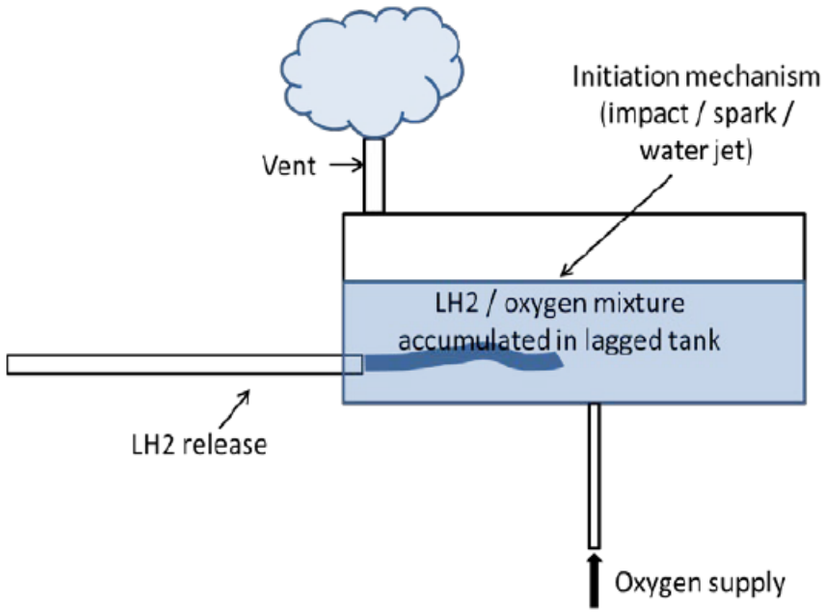


E4.5 Ignition of H_2/condensed O_2 phase

- Ignition of accumulated LH_2/solid air/oxygen (i.e. condensed phase)
  - LH_2 released vertically downwards for a fixed duration
  - Exposed to different stimuli
  - Pressure measurements and video footage

E4.5 Ignition of H_2/condensed O_2 phase

- LH_2 collected in a vessel and subject to the same stimuli



May form condensed O_2/ N_2 separately initially then mix with LH_2

HSL Technical Team

- Project Technical Lead: Simon Coldrick
- Experimental Lead: Jonathan Hall
- Electrostatics: Darrell Bennett
- Experimental assistants: TBC
- HSL Advisors: Phil Hooker / Mark Royle / Debs Willoughby / Stuart Hawksworth