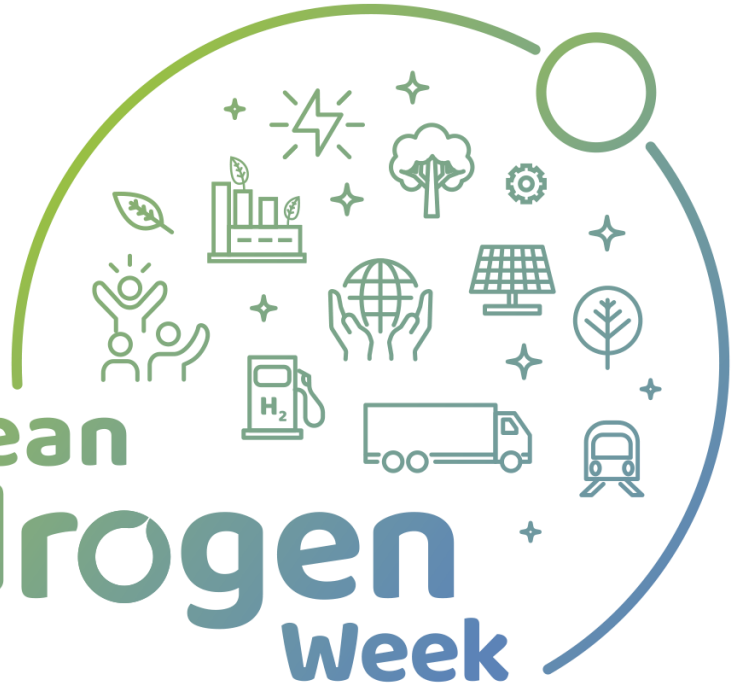
PRESLHY

Pre-normative Research
for the Safe use of Liquid HYdrogen



Thomas Jordan

Karlsruhe Institute of Technology

www.preslhy.eu

thomas.jordan@kit.edu

#PRD2021
#CleanHydrogen

European Commission

Project Overview

- Call year: 2017
- Call topic: FCH-04-4-2017: PNR for a safe use of liquid hydrogen
- Project dates: 01/2018 – 05 /2021
- % stage of implementation 01/11/2019: 100 %
- Total project budget: 1 905 862,50 €
- FCH JU max. contribution: 1 724 277 €
- Other financial contribution: -

European Hydrogen Week

PRESLHY Partners

#PRD2021
#CleanHydrogen

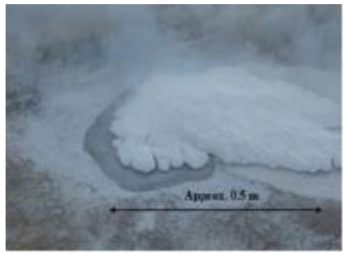
FCH

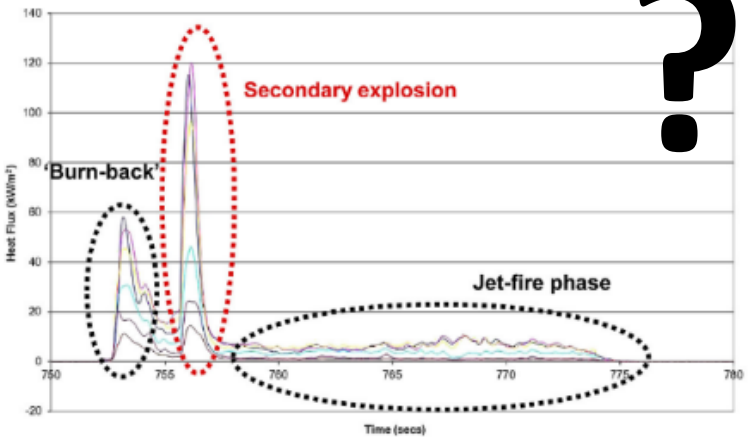
European Commission

PRESLHY Motivation




- Scale-up of existing and new applications increase H2 demand.
- Liquid hydrogen (LH2) provides **larger densities** and gains in **efficiency** and **potentially reduces risks** compared to compressed gaseous transport and storage
- Many **knowledge gaps** wrt accidental behavior of LH2 and **inconsistent** and **potentially over-conservative RCS** (e.g. NFPA 2 and EIGA)

#PRD2021
#CleanHydrogen

European Commission

PRESLHY Main Objectives

- Report **initial state-of-the-art and knowledge gaps** with priorities with respect to the intended use of liquid or cryogenic hydrogen technologies
- Execute adjusted **experimental program** addressing release, ignition and combustion phenomena with highest priorities

→ Close knowledge gaps

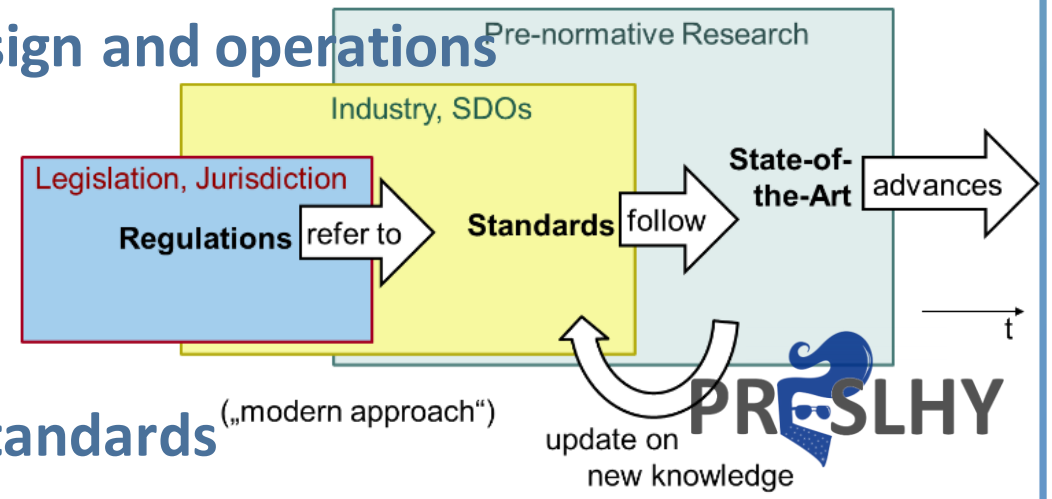
- Develop **suitable models and engineering correlations** and integrate them in a suitable open risk assessment toolkit

→Provide enhanced recommendations for safe design and operations

of liquid or cryogenic hydrogen technologies

- Support international SDOs in updating of existing standards or developing of new international

→ Support development of performance based, risk informed, internationally harmonised standards



- Document and publish detailed, aggregated and interpreted data in a FAIR way and
- disseminate the **enhanced state-of-the-art**

PRESLHY Networking

European Hydrogen Week

hySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

EHSP
RCS SCG

JRC (HIAD)

ISO TC 197
CEN/CENELEC TC6

IEA Hydro… Tas…

US DOE

ISO/PWI 24077: „Safe Use of LH2 in Non-Industrial Settings“ established on 6.12.2018

Presentation at CEN/CENELEC on 28.01.2020

Presentation at IEA Safety Task on 19.10.2018

Common Workshops on 06.03.2019 and Spring 2021

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

WP1 – Manage-ment (KIT)

WP2 - Strategy (AL)

WP3 – Release & Mixing (NCSRD)

WP4 – Ignition (HSE)

WP5 – Combus-tion (KIT)

WP6 – Implementation (UU)

Advisory Board

H2@Scale
U.S. Department of Energy

SH2IFT

GexCon, IFE, Equinor + Shell

KHI, Toyota

Project Achievements

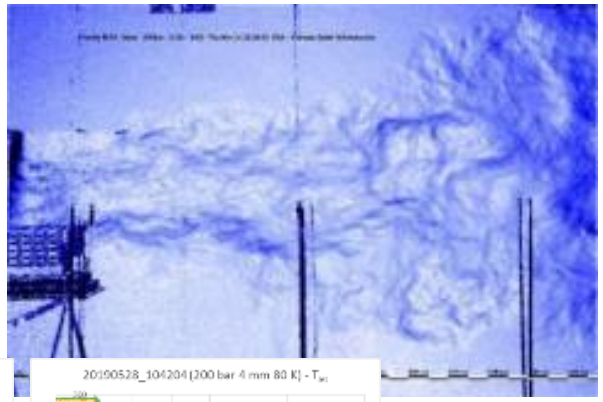
Achievement to-date

INCONSISTENT, RCS WITH A FRAGMENTED INCOMPLETE SCIENTIFIC BASIS

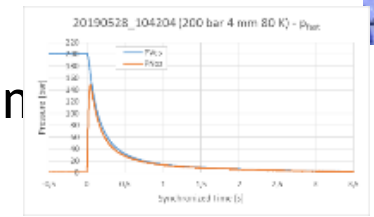
RISK INFORMED, HARMONISED INTERNATIONAL STANDARD FOR SAFE USE OF LH2 IN NON-INDUSTRIAL SETTINGS

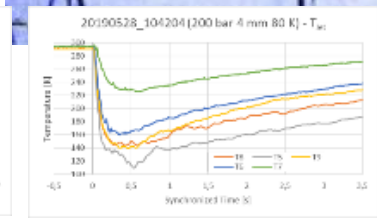
- Initial state-of-the-art, RCS and research priorities documented
- Extensive experimental program on highly ranked priorities completed
- Some relevant knowledge gaps closed with respect to release/mixing, ignition and combustion
- Set of engineering tools, guidelines for RCS and White Paper compiled
- ISO (TC 197) and CEN (SFEM WG Hydrogen) informed and **update of ISO TR 15916:2015 wrt safe use of LH2 initiated** within WG29

Closed Knowledge Gaps - Release



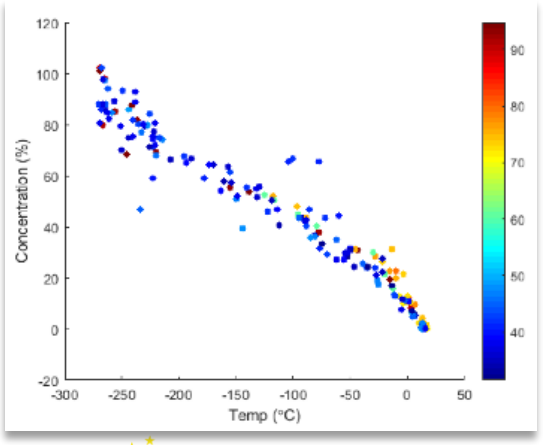
- 1 D model for multi-phase release including non-equilibrium processes





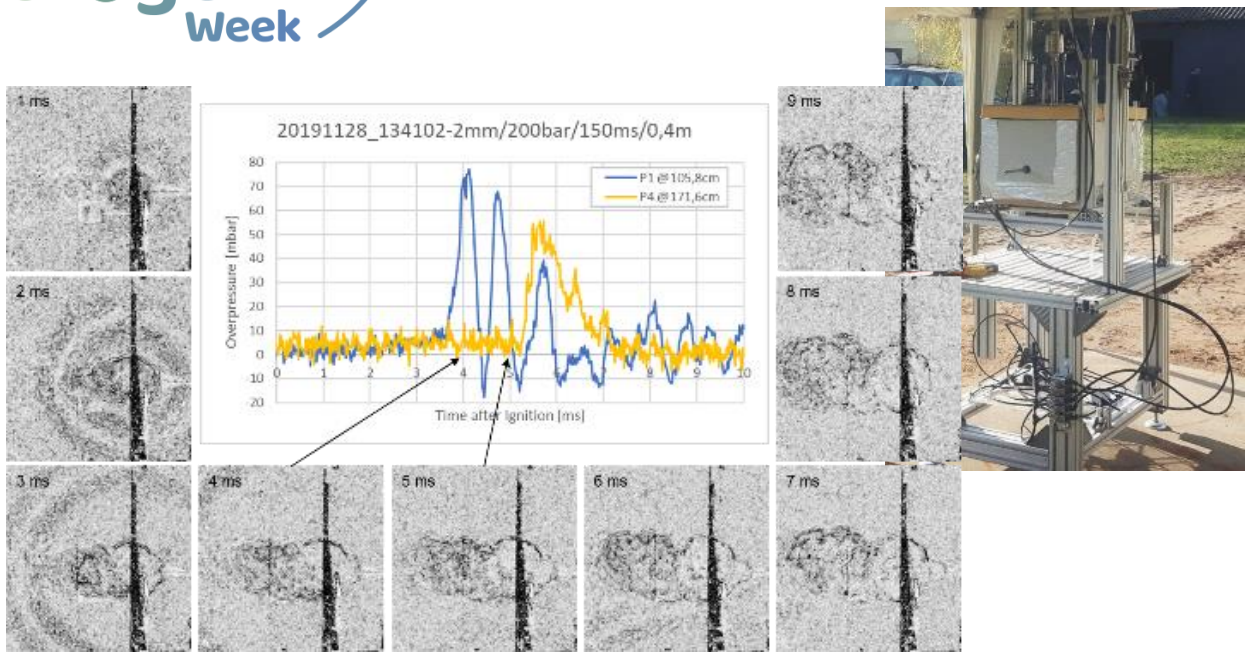
- Discharge coefficients for circular nozzles D=0.5-4 mm
  5 - 200 bar; 20 – 300K (KIT/PS E3.1 DISCHA tests)
  see https://doi.org/10.5445/IR/1000096833

- No rainout for large scale above ground horizontal releases
  (HSE E3.5: rainout tests)



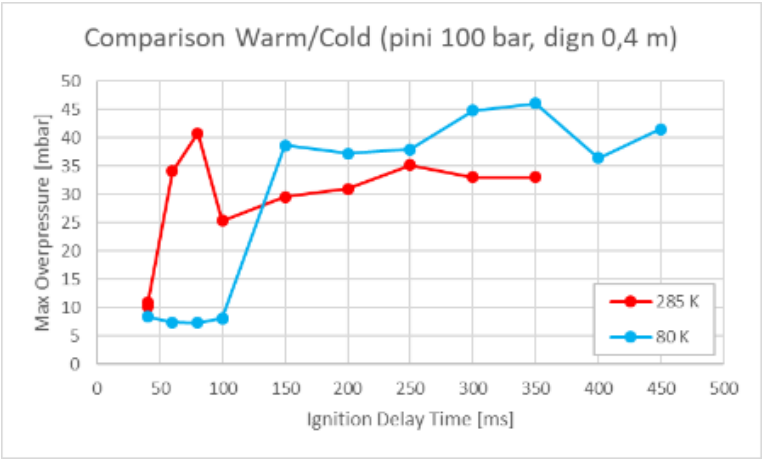
- Correlation of T and concentration of mixtures of H2 with cryogenic origin and air

Closed Knowledge Gaps - Transient Combustion Effects



> 100 Ignited jet tests combined with discharge experiments E5.1
T = 80K .. 300K
p = 5 .. 200bar
D_{nozzle}= 0.5 .. 4mm

Iterative procedure for identifying most critical ignition time and location

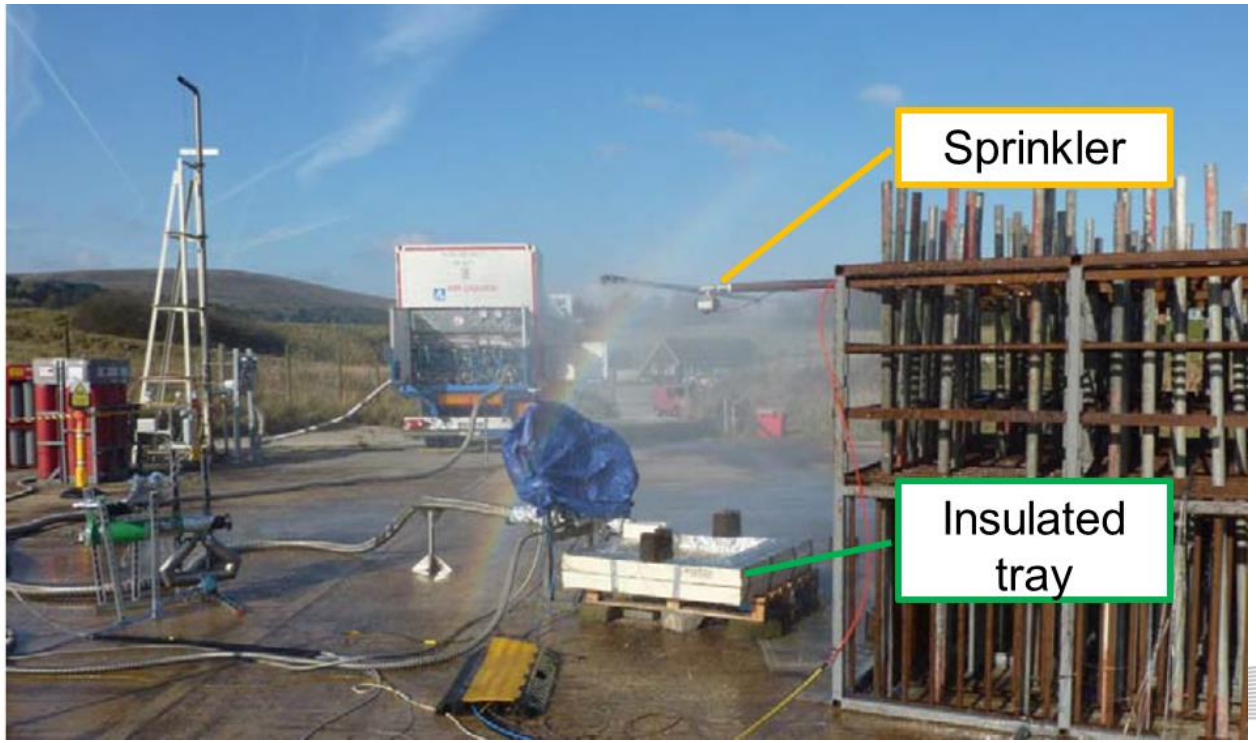


- Better understanding of transient jets and combustion processes
- Inventory based map of worst effects (pressure & thermal)
- to be extrapolated to large inventories for RCS

#PRD2021
#CleanHydrogen

Closed Knowledge Gaps - Multi-phase accumulations with explosion potential

- Repeated spills in gravel bed might generate highly reactive condensed phase mixtures – not on other substrates (E4.4 Ignition above pool)



- Water sprays on LH2 and LH2 spills on small water pools non critical (E4.4 and E4.X)

Closed Knowledge Gaps - Combustion in confined/congested domains

- Stronger pressure loads for cold tests in comparison with warm tests with the **same volume**, hydrogen concentration and blockage ratio (scale to inventory?)

E5.3 Semi-confined channel at KIT/PS


E5.5 Test set-up at HSE, Buxton

- Increase in **critical and effective expansion ratios** determine flame acceleration in cryogenic mixtures
- **Reduced run-up distance** for detonation transition DDT in cryogenic mixtures (← density effects)
- Influence of blockage ratio on DDT less pronounced
- Effects in free unconfined domains to be investigated

PRESLHY Exploitation Plan and Expected Impact

Exploitation

- Closure of knowledge gaps
- Developing models for hazard evaluation and risk assessment
- Enhancing the state-of-the-art
- Deriving recommendations for users and SDOs
- Initiating review or development of standards

Impact

Enabling the safe and economic introduction of LH2/cryogenic hydrogen technologies with a flexible, but robust framework consisting of

- improved knowledge basis
- consistent recommendations
- performance-based, harmonized specific standards to be referred by regulation

Outreach

www.preslhy.eu

PRESLHY Exploitation & Dissemination Activities

Management (WP1)

Implementation (WP6)

Task 1.3 Website

Data Management

Engineering tools

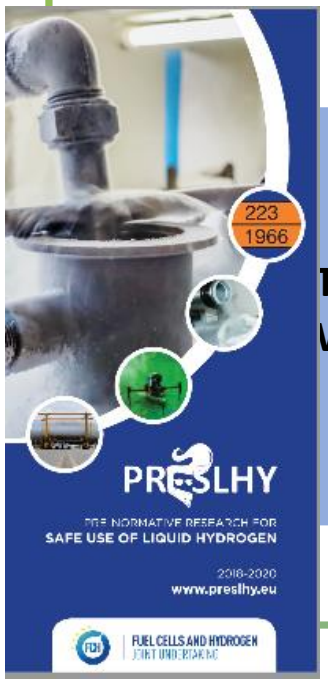
Handbook

Guidelines

RCS Recommendations

White Paper

Task 6.6 Dissemination Conference



#PRD2021
#CleanHydrogen

PRESLHY
PRENORMATIVE RESEARCH FOR
SAFE USE OF LIQUID HYDROGEN
Research and Innovation Action supported by the FCH JU, Grant Agreement No 779613, 2018-2020, www.preslhy.eu

First announcement
Dissemination conference of PRESLHY project
5-6 May 2021, Athens, Greece

We are pleased to invite you to the conference concluding PRESLHY project on pre-normative
e use of liquid hydrogen. Speakers from PRESLHY consortium will present the
standing research performed on the major phenomena associated to the release
f liquid and cryo-compressed hydrogen, the ignition of cryogenic hydrogen-air
ir combustion. The conference will address the potential impact of the project
ernational community working on hydrogen and fuel cell technologies.
invited international speakers will enrich the
nce program, providing a
ew of the state of the art and worldwide research
afety of liquid hydrogen.

Date and venue
The conference will be held on the 5-6 May 2021 in Athens, Greece. Future announcements will include further updates and details on the conference venue, taking into account the developments of Covid-19 pandemic and possibility of a virtual even

ration to the
charge as it
under grant
tence costs.
considered

ng under the
greement No

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

PRE-NORMATIVE RESEARCH FOR
SAFE USE OF LIQUID HYDROGEN

Acknowledgement

The PRESLHY project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation program under the grant agreement No 779613.

Horizon 2020
European Union funding
for Research & Innovation

… and many thanks to all contributors
(e.g. Equinor, SHELL, …)