Enhance Safety Knowledge for Hydrogen Measurements/Modelling in cryOgenic phase

ESKHYMO

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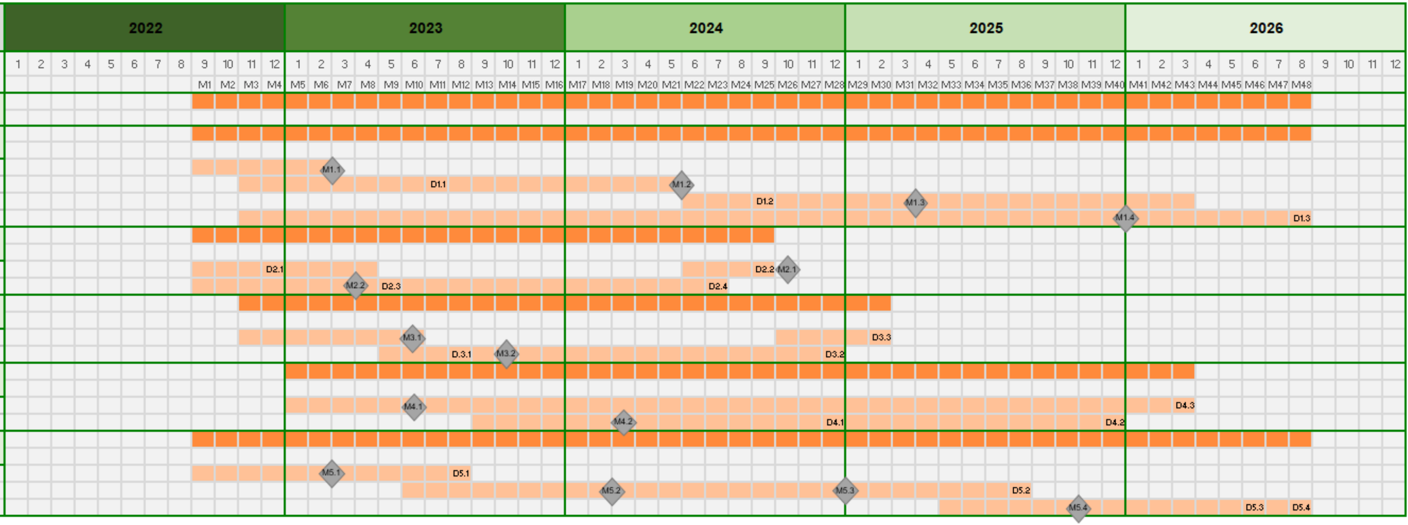
in the name of E. Havret (project coordinator)

Eskymo in a nutshell

- **ESKHYMO is a research project pertaining to the safety aspects of the use of liquid hydrogen financed by the French national research agency (ANR). The project has started officially on 3rd October 2022 and will last 4 years.**
- **Our consortium is composed of 5 partners:**
  - INERIS,
  - Air Liquide
  - ICARE laboratory from CNRS,
  - IMFT,
  - 4 laboratories from CEA (CEA Liten is the coordinator)
- **The research topics covered by the project ESKHYMO are :**
  1. Quantifying the physical phenomena involved in a cryogenic tank consecutive to air ingress,
  2. Understanding the kinetic of LH2 evaporation during spillage
  3. Predicting the size of flammable clouds in case of LH2 spillage,
  4. Predicting the severity of ignition flammable clouds following a LH2 spillage.
- **The project will deploy both modelling and experimental activities to better characterize and understand the phenomena that are involved.**

Timeline of the project

Work Packages description	Resources: WP&Task Leader	Resources: WP m.m
WP0 Management	**CEA**	**10.5**
WP1 Quantifying the physical phenomena involved in a cryogenic tank consecutive to air ingress	**CEA**	**42.5**
T1.1 Review of available thermal fluxes	CEA	
T1.2 Design and manufacturing of the test bench	CEA	
T1.3 Thermal flux measurements	INERIS	
T1.4 Comparison modelling/measurement	AL	
WP2 Understanding the kinetic of evaporation of LH_2 during spillage	**CEA**	**59**
T1.1 Evaporation kinetic - Numerical approach	INERIS	
T2.2 Evaporation kinetic - Experimental approach	CEA	
WP3 Predicting the size of flammable clouds in case of LH_2 spillage	**INERIS**	**58**
T3.1 Dispersion characterization - Numerical approach	AL	
T3.2 Dispersion characterization - Experimental approach	INERIS	
WP4 Predicting the severity of the ignition of flammable clouds following LH_2 spillage	**CNRS**	**58**
T4.1 Severity in case of ignition: Numerical approach	IMFT	
T4.2 Severity in case of ignition: Experimental approach	CNRS	
WP5 Industrial background, findings application and dissemination	**AL**	**11.9**
T5.1 Description of LH_2 ecosystem	AL	
T5.2 outcomes	CEA	
T5.3 management	INERIS	



Work package structure

- **The project is composed of 5 WP**

  - WP1 - Quantifying the physical phenomena involved in a cryogenic tank consecutive to air ingress
  - WP2 - Understanding the kinetic of LH2 evaporation during spillage
  - WP3 - Predicting the size of flammable clouds in case of LH2 spillage
  - WP4 - Predicting the severity of ignition flammable clouds following a LH2 spillage
  - WP5 - Industrial background, findings application and dissemination

➔ **Let's now go into details for each WP**

WP1 – Behavior of an insulated tank

Typical accident for cryogenic tanks or circuits:

- Loss of insulating vacuum due to leakage.
- Often the more severe: **air ingress** ➔ pressure relief device is mandatory

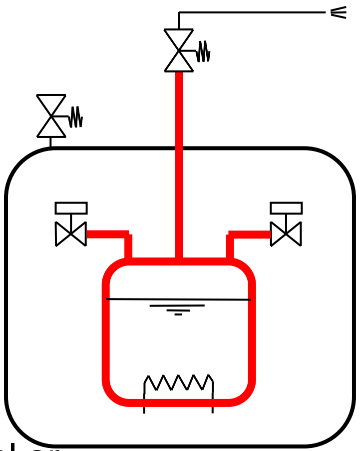
Four steps to size it:

- Power arriving on the system
  ➔ **need to know the thermal flux during accidental scenarii**
- Calculation of the mass flow rate to evacuate
- Calculation of the pressure relief device upstream conditions
- Sizing of the safety device

For hydrogen the available input data about the thermal flux are poor and have to be completed

- This is the main objective of this work package by the manufacturing of a cryostat dedicated to this kind of measurement.

WP1 – Experimental set-up



A dedicated cryostat will be built

- Thermal flux measurement on tanks filled with liquid hydrogen
- Possible modifications:
  - Replacement of the tank to adapt the maximum allowable pressure (subcritical or supercritical discharge)
  - Adaptation of the instrumentation depending on the thermal flux to measure, possibility to test new measurement method
  - Capability to perform air ingress, hydrogen ingress, nitrogen ingress…
  - Modification of the discharge line to adapt its geometry (volume, diameter…)
  - Easy change of the thermal insulation: with or without MLI, aerogel…

Expected measurements

- Flowmeters, thermometers, void fraction of the fluid, level of liquid

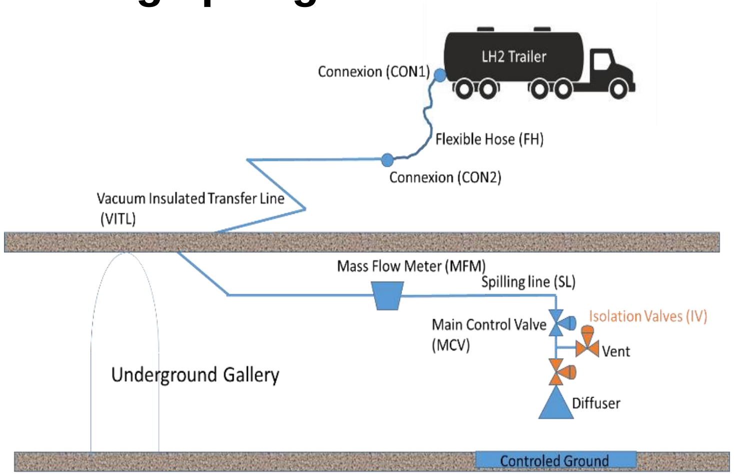
WP2 – Spillage characterization

Main objective :

Understanding the kinetic of LH_2 evaporation during spillage

A dual approach:

- modelling
  - Algebraic / integral models (Hypond, …)
  - CFD simulations (Neptune CFD, …)
- experiments
  - Scaled experiments: pool size around 1 m²
  - Control of the release conditions

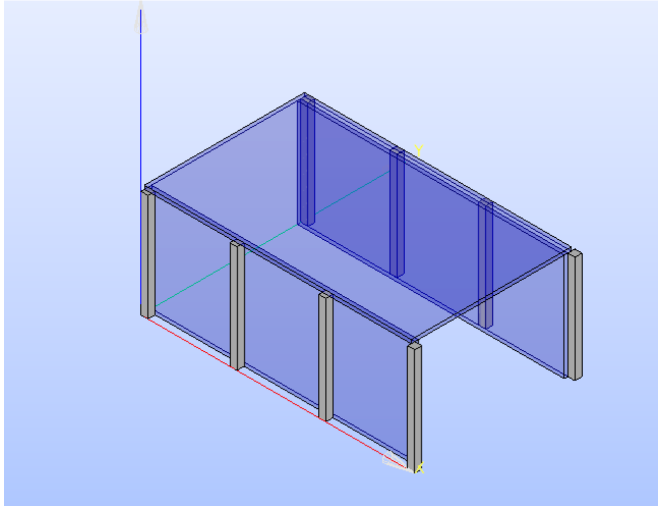


WP3 – The flammable cloud

Explosion consequences directly depend on the cloud characteristics correct modelling of the cloud if a key milestone ➔ need for reliable data

Dispersion in a controlled environment

- Air flow: velocity and profile
- Transparent roof (and walls) with visualization



Two set of hydrogen releases

- LH_2 pool evaporation
- Cold gas release through a porous media

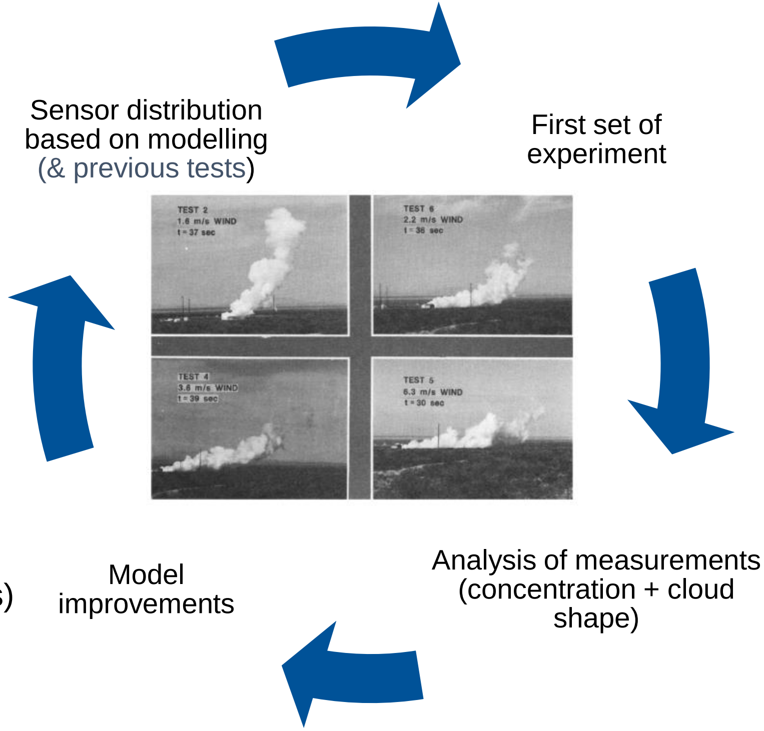
WP3 – And once more, a dual approach

Model to design experiment

Experiment to improve models

A detail set of measurements

- Local concentration measurement (catharometric technology)
- Raman system: based on optical fiber distribution
- Tomography method, based on visible cameras
- Velocity and turbulent velocity measurements (Mac Caffrey probes)
- Temperatures, based on thermocouples



WP4 – Cloud explosion

Ignition of the formed hydrogen cloud

- Either resulting from the pool or from the gas release (or both)
- But also
  - Laboratory scale tests to provide fundamental data regarding the combustion of H2/air at very low temperatures
  - Medium scale tests in a cylindrical vessel to provide high precision measurements

Combination of numerous measurement systems

- Gas sensors, thermocouples
- High frequency pressure transducers
- FAIRS – Absolute radiative flux at high resolution
- High speed imaging, Raman spectroscopy

+ numerical simulation

WP5 – The link with industrial needs

Using LH2 is mandatory for hydrogen energy large scale development

- Reducing delivery footprint and optimizing the availability for gaseous hydrogen uses
- Make possible cryogenic hydrogen system (trucks, planes, …)

A relevant regulation will be required

- Detailed characterization of possible scenarios
- Associated safety distances

Thanks!