Fuel cells and hydrogen

Joint undertaking

Programme Review Day 2012

Brussels, 28 & 29 November 2012

New Energy World JU

fuel cells & hydrogen for sustainability

http://www.fch-ju.eu/

HyCOMP

Enhanced Design Requirements and Testing Procedures for Composite Cylinders intended for the Safe Storage of Hydrogen

(Grant Agreement N° 256671)

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Air Liquide

Project presentation

- HyCOMP is a Pre-Normative Research (PNR) project on composite storage tank
- Launched in January 2011
- Budget: 3 802 542 € of which 1 380 728 € (36 %) is funded by FCH JU
- Partnership:

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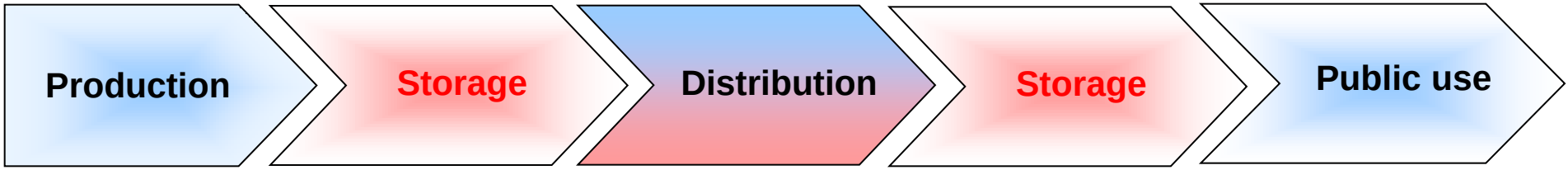
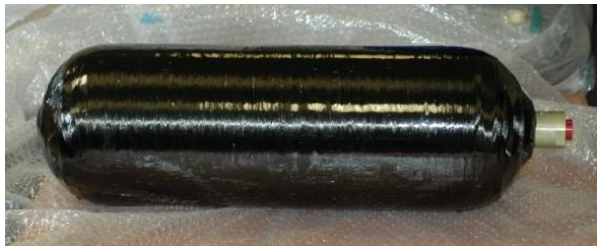
Project presentation

- Context:
  - Hydrogen storage is a key issue for the extensive use of H2 as an energy vector & success of the whole hydrogen value chain



- The most mature technology for storing hydrogen is in **compressed form** in high-pressure cylinders

High pressure storage of H_2 (700 bar) in **carbon fiber composite cylinders**
=> most advanced technology at this stage



9L cylinder especially designed for HyCOMP

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Project presentation

- Composite cylinders are already in use in application markets
  - Automotive onboard storage
  - Transport of compressed hydrogen
  - Stationary storage

- Key issues:
  - Current regulations do not allow one to exploit the full potential of CF materials
  - No scientifically established rationale for determining service lifetime
  - New and revised standards are in process, but the work is done based on traditional and conservative way of determine the performance of a cylinder

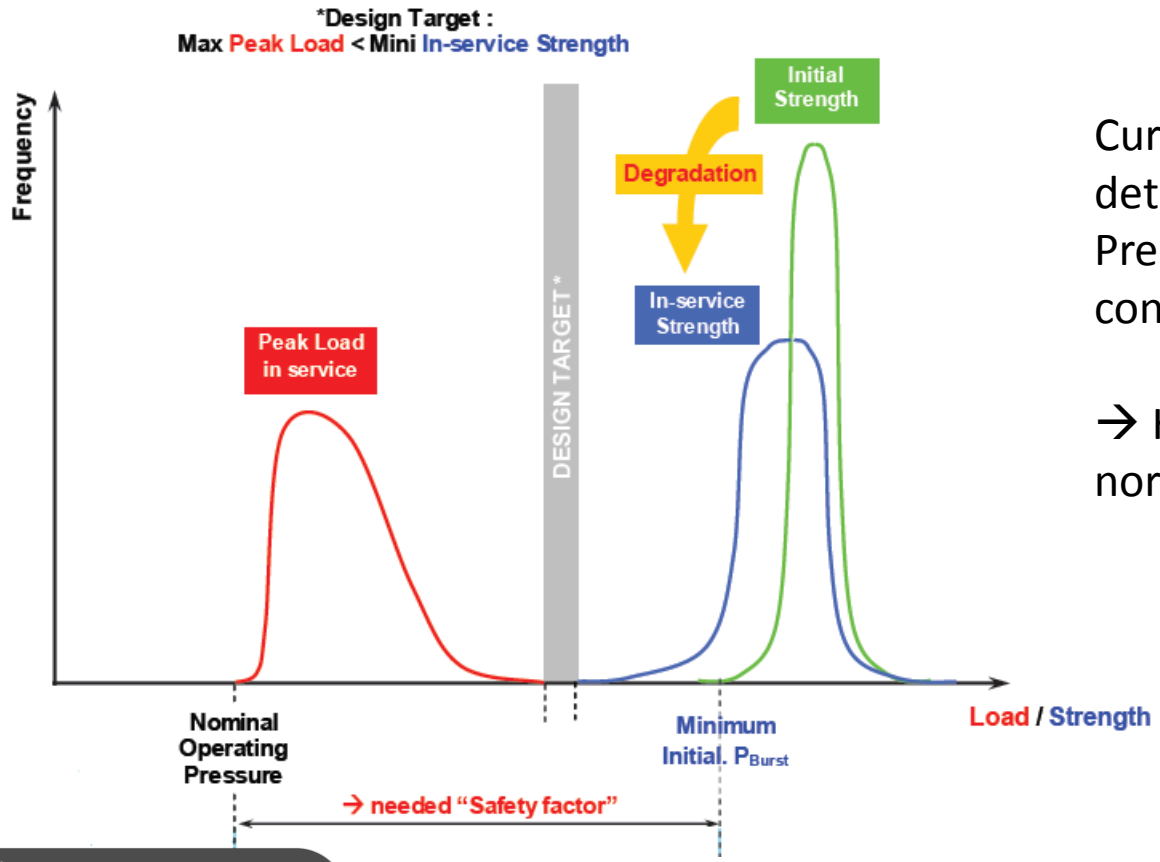
A change in Regulation, Codes and Standards will most likely not be possible without a better **understanding of damage accumulation mechanisms** & kinetics under typical loads in service (static and cyclic loads)

Project presentation

- Principal objectives:
  - To **enhance design requirements** for composite cylinders for storage or transport of compressed hydrogen
  - To improve the full set of requirements defined for **ensuring the structural integrity** of the cylinders throughout their service life (covering design type approval, manufacturing quality assurance, and in-service inspection)
  - To **improve procedures** for type approval and batch testing

- Main outcome:
  - Recommendations for **improving the applicable European and international standards and regulation** on high-pressure hydrogen cylinders for automotive, transport and stationary applications
    - Fully performance-based design criteria (including acceptable stress ratios for fibres) for composite cylinders allowing to optimize design
    - More specific qualification test programs for an improved cylinder manufacturing quality control
    - A common rationale and improved methods for determine remaining performance (lifetime) of the cylinders

- Conceptual framework for justification of design



Current designs are mainly determined by Stress Ratio/Burst Pressure ratio requirement, considering **stress rupture**

→ Hycomp focuses on loads from normal service :

- Static
- Cyclic

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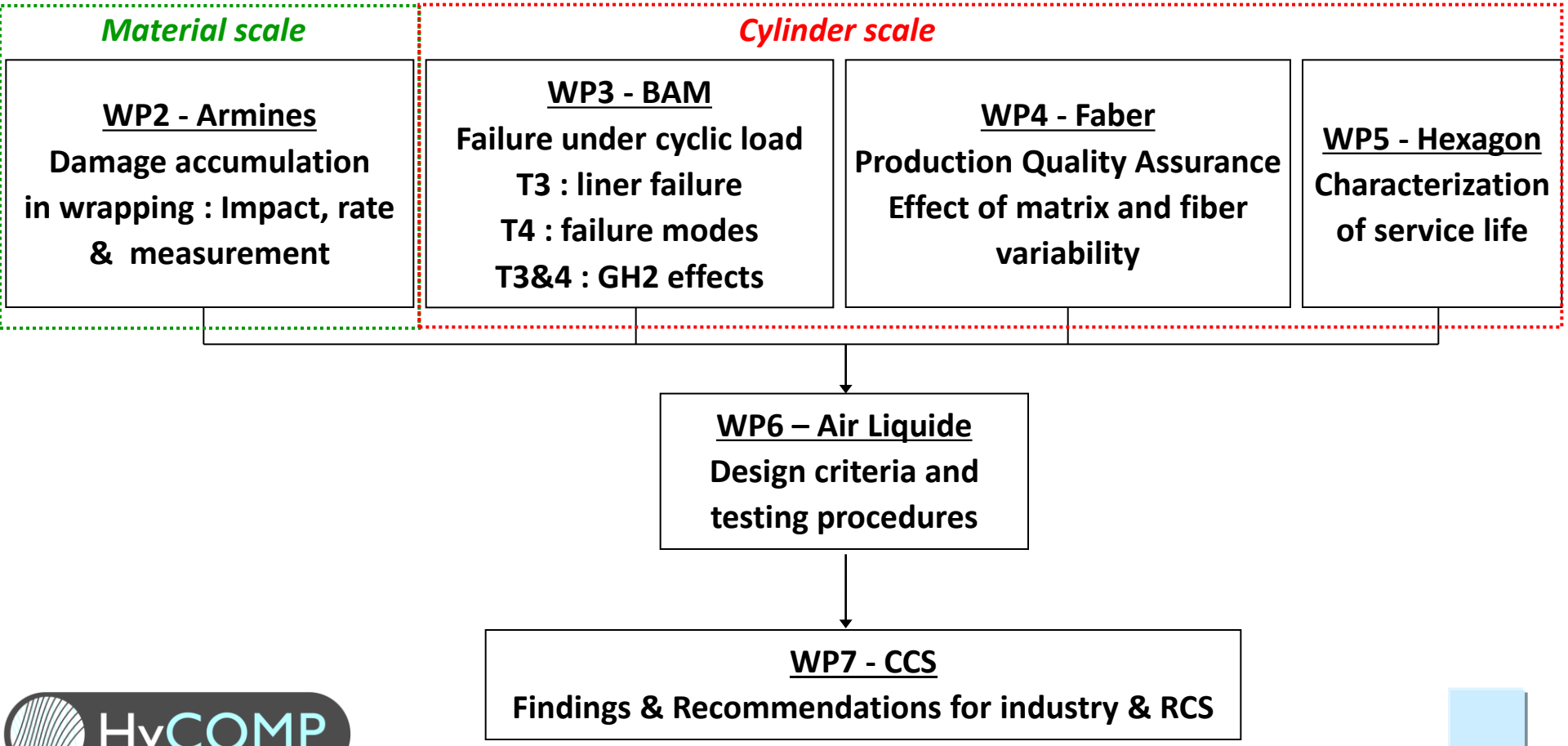
Project presentation

- Approach in performing the activities:



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Project achievements

WP1: Management

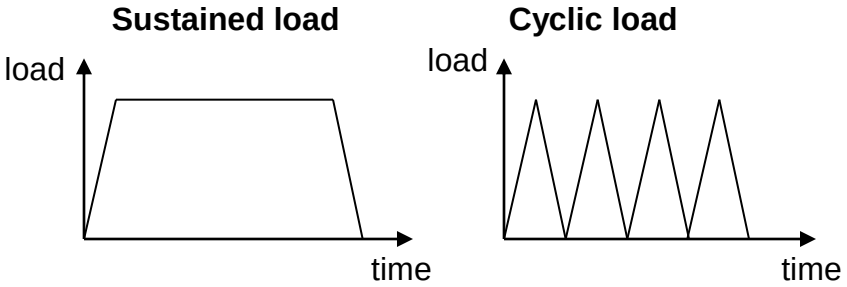
A public website has been designed and is available for consultation at the following address: http://hycomp.eu

Project achievements

WP2 objectives & achievements

➢ Generation of data on damage accumulation in the carbon fiber composite wrapping at a material scale

- What is the impact of operational loads on the long-term properties of the composite?
- At what rate does damage accumulate in function of load conditions ?



Environmental conditions:

- Temperature
- Humidity

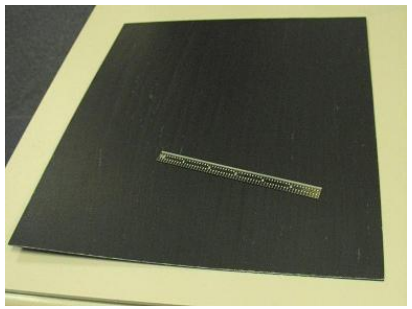
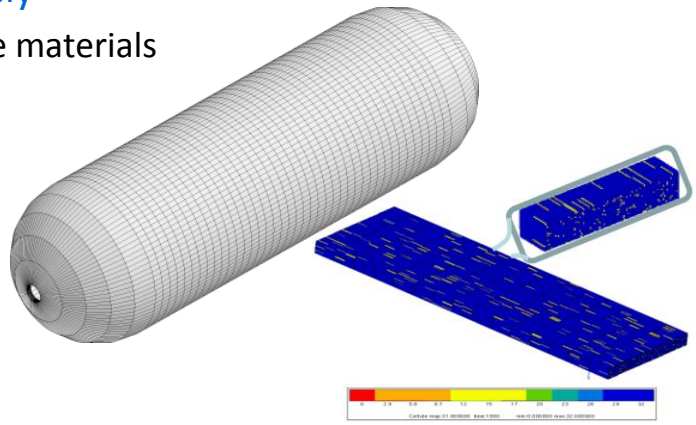


Plate specimens

- Identification of limit up to which material can be used safely
  - Methodology to estimate the level of damage in composite materials (based on **Acoustic Emission**)

➢ Development of models predicting damage accumulation

- Two approaches are envisaged : a fractal approach (WUT) and a finite element modeling (Armines)



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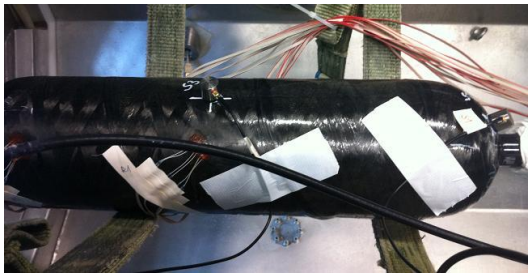
Project achievements

WP3 objectives

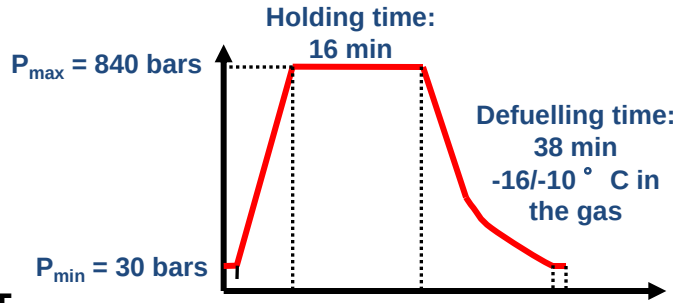
- Extend the degradation mechanisms identified at a material scale on cylinders *(macro-level)*: investigations on T3 and T4 cylinders
  - Establish critical load levels (pressure, temperature and hydrogen exposure) on composite wrapping that might develop unacceptable failure modes within specified service conditions for composite cylinders



T3 cylinder (9L) from Faber

T4 cylinder (19L) from Hexagon

- Study of specific issues:
  - Effects of composite degradation on internal load sharing between liner and wrapping for type III cylinders, and cycle life as a result
  - Effect of cycle depth on cylinder performance
  - Effects on composite of heating/cooling during gas pressure cycling



Pneumatic test at the **JRC-IET reference laboratory** on own funding

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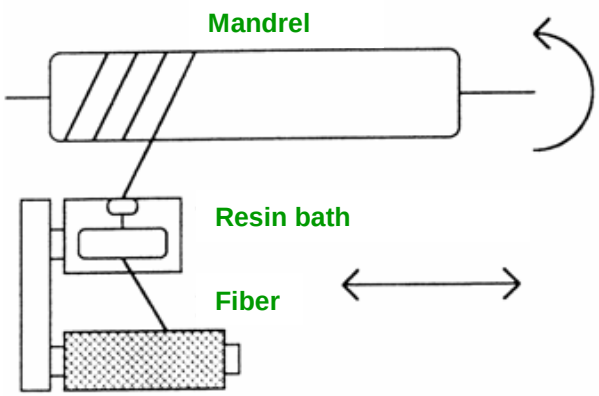
WP4 objectives & achievements

- Provide the basis for updated normative requirements for ensuring that manufactured cylinders will behave as observed under type approval.
  - Identification of the essential material and manufacturing parameters that should be subject to a **quality assurance plan** because they determine the cylinder performance and its resistance to long-term degradation



Materials and process parameters:

Filament materials, resin system

Impregnation, winding geometry, winding speed and tension, curing

- Evaluation of possible approaches for control of the final product using NDT (non-destructive testing) methods
  - The preferred technique is **Acoustic Emission**

Project achievements

WP5 objectives & achievements

- Review of accidents of composite cylinders used for the storage of flammable gases
  - Only a few composite cylinders has failed in-service (mainly due to vehicle fire)
  - Composite cylinders designed according to current standards present a high level of safety
- Determine the operational conditions (gas pressure-related loads and temperature conditions) for which the cylinder needs to be designed
  - Collect data for 3 different applications:
    - Automotive use, Stationary use and Transport
  - Compare with data from WP2 and WP3 to ensure that the critical operational loads have been properly addressed
- Analyze accidentally induced failure modes (critical accidental energies)
  - How the combination of stress level/cycle load and accidental impact will influence the momentary performance and the life time performance of composite cylinders?
- Compare the most damaging service conditions to actual performance capacity for the different applications defined above

Project achievements

WP6 objectives & achievements

- Define appropriate and cost effective testing protocols based on WP2 to WP4 results, to demonstrate a cylinder's fitness for service and resistance to its anticipated service life
  - **Design requirements** ensuring that risk limits are met for specified lifetime for each vessel technology and each identified application
  - Improved procedures for **design type testing**
  - Batch tests procedures for **manufacturing quality assurance**
  - Methods and procedures for **inspection in service**
  - Appropriate **pass/fail criteria** for the above tests and inspection procedures

- Review of existing published and draft RCS documents (e.g. ISO, ADR, TPED)
  - ISO/DIS 15869 - *WG6 - Gaseous hydrogen and hydrogen blends - Land vehicle fuel tanks*
  - ISO/CD 15399 - *WG15 - Gaseous Hydrogen - Cylinders and tubes for stationary storage*
  - ISO/FDIS 11119 parts 1, 2 and 3 - *Gas cylinders - Refillable composite gas cylinders and tubes - Design, construction and testing (Transportable storage)*

Project achievements

WP7 objectives & achievements

- Summarize the findings and recommendations concerning the safe storage of compressed hydrogen in composite cylinders
  - Extract and prioritize recommendations to support Regulations Codes and Standards (RCS) initiatives at the international level
  - Provide a comprehensive path forward that will define how the project findings can be integrated into ongoing or new RCS activities

- Disseminate the project results so that they can be used by the international hydrogen and fuel cell community
  - Organization of a **workshop** in conjunction with an international Hydrogen and Fuel Cell event (in 2013)

- Automotive Advisory Group:
  - Aim: to get the adhesion and the support of the Automotive Industry in the scientific approach performed in HyCOMP
  - **Daimler** and **Opel/GM**

Alignment to MAIP / AIP

Relevance and contribution to MAIP

- “Address design & test criteria for high pressure composite storage tanks“ (MAIP)
- Hydrogen storage tanks are critical part of the supply chain for the 4 application areas

Transport & refueling infrastructure	Stationary power generation & combined heat and power
Hydrogen production & distribution	Early markets

- The reliability of safe H2 storage tanks is crucial for the development of H2 as an energy vector

Alignment to MAIP / AIP

Comments on priorities and topics of AIPs

- Pre-normative research (PNR) on damage accumulation in composite cylinders for the storage of H2 is a way to improve their safety
  - PNR is critical to reach deployment targets

- More efforts are needed on:
  - Development of adequate in-service inspection methods and procedures for composite cylinders in order to ensure an optimized fitness for service
  - Quantification of the effect of mechanical impacts on composite pressure vessels and definition of improved criteria for removal of service
  - Fire safety of pressure vessels in composite materials
  - Recycling of composite cylinder
  - Carbon fiber manufacturing to reduce costs

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Stakeholder involvement / Dissemination:

- Automotive Advisory Group
  - Objectives:
    - Characterization of the service profiles and worst case conditions to be considered for the automotive application
    - Identification and characterization of proposals for change in RCS from the automotive industry
    - Harmonization of the work in progress in HyComp with proposals and views on the activity in HyComp seen from the automotive industry
  - 3 meetings planned during the project

- A workshop in a Hydrogen and Fuel Cell conference or event will be organized to disseminate the project results so that they can be used by the international community *(industrial stakeholders and academics)*

Cross-cutting issues

Regulations, Codes and Standards

- HyComp will extract and prioritize recommendations to support RCS initiatives at the international level (cylinder tests & design criteria) (cf.WP7)
- These recommendations will include (cf. WP6):
  - Fully performance-based design criteria (including acceptable stress ratios for fibres) for composite cylinders allowing to optimize design
  - More specific qualification test programs for an improved cylinder manufacturing quality control
  - A common rationale and improved methods for determine remaining performance (lifetime) of the cylinders
- Expected deliverables:
  - Report on recommendations for design and testing (D7.2)
  - Summary report on recommendations to support Regulations Codes and Standards initiatives (D7.3) to define how the project findings can be integrated into ongoing or new RCS activities

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- Collaborations / Technology Transfer:
  - **Standards and regulation**:
    - Most partners directly contribute to international standards (ISO) and regulation development
  - Expected collaborations with other projects:
    - **StorHy** (European project, finalized in 2008)
    - **InGas** (2008-2011)
    - **H2E** (2009-2017) : a French funded project dedicated to early markets
    - **Toledo** (2011-2013): a French funded project dedicated to accidental loads on composite cylinders
    - **HyCube** (2014)

HyComp will seek corporation and information exchange if beneficial for the project purpose and given acceptance from all parties involved

Project future perspectives

- Perspectives:
  - Short term:
    - To complete the experimental test program on specimens and cylinders
    - To develop a relevant model predicting residual lifetimes, based on damage accumulation in the composite for a given load
    - To summarize the findings and extract recommendations for RCS
  - Long term:
    - To implement the project findings in international standards
    - To reduce the safety factor while ensuring cylinder structural integrity and safety

Thank you for your attention

Any questions ?

http://hycomp.eu

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