PRE-NORMATIVE RESEARCH ON GASEOUS HYDROGEN TRANSFER

FIRST PROJECT HALF OF HYTRANSFER: PUBLIC SUMMARY

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Coordination	Industry	Research & Testing	Regulations, Codes & Standards	Funding
ludwig bölkow systemtechnik	AIR LIQUIDE, HONDA The Power of Dreams, HEXAGON COMPOSITES	European Commission, INSTITUT P' CNRS - UPR 3346, TESTNET ENGINEERING	CCS GLOBAL	New Energy World JU

Disclaimer

1 PROJECT CONTEXT AND OBJECTIVES

The project HyTransfer addresses theme SP1-JTI-FCH.2012.2.6 from the European Fuel Cells & Hydrogen Joint Undertaking Annual Implementation Plan (AIP 2012). The objectives have not changed since project begin.

Challenge: Overheating and Overcooling during Hydrogen Filling

Hydrogen transfer concerns filling and emptying processes. Filling generates heat which can lead to overheating of composite pressure vessels when filling transportable containers, onsite storage gas vessels or fuelling vehicles. Emptying generates cooling. Excessive cooling may occur during delivery of hydrogen from a trailer. Today's regulations, codes and standards (RCS) focus on limitation of gas temperature. Figure 1 demonstrates that maximum gas temperature (here: nitrogen) is not equal to experienced maximum temperature of the tank material.

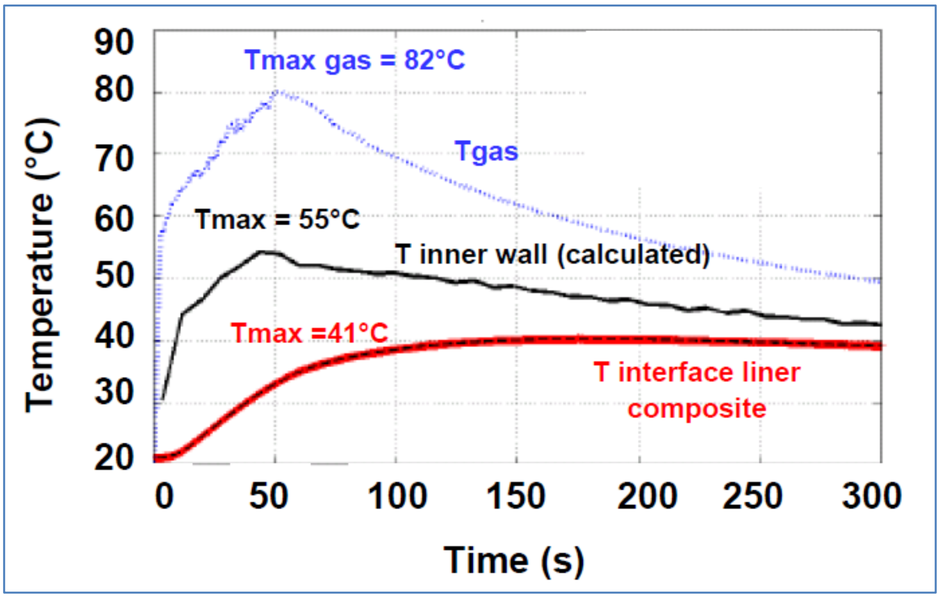

Figure 1 **Temperature evolution of the gas, the interface between the liner and the composite (measured) and the inner wall in contact with the gas (calculated) during filling of a 90L type 4 tank with nitrogen to 9 MPa (204g/s) (copyright: Air Liquide / CNRS)**

Aim: Converting New Filling Approach into RCS Recommendations

HyTransfer aims to develop and experimentally validate a practical approach for optimizing means of temperature control during fast transfers of compressed hydrogen to meet the specified temperature limit (gas or material) taking into account the container and system's thermal behaviour.

Finally, conditions shall be created for an uptake of the approach by international standards, for wide-scale implementation into refuelling protocols. The new approach will be thus evaluated and its benefits quantified with regards to performance, costs, and safety. To reach this, recommendations for implementation into international standards will be proposed in November 2015 when the project is concluded.

Approach: Tank Wall Temperature is Critical

As hydrogen vehicle refuelling is the leading application, the project will thus focus on fast filling of composite tanks. To avoid overheating, the speed of transfer has to be limited or the gas to be cooled prior to introduction. Both solutions impact on performance and cost, therefore temperature control is essential for optimization of gas transfer. Temperature limits on hydrogen transfer can be applied to material that must not exceed design temperature (e.g. 85°C), or to the gas that must not exceed a specific limit. A model is being developed for a better understanding of the thermal behaviour of the tanks, the results obtained with this model will be compared with those obtained from experiments to confirm its accuracy.

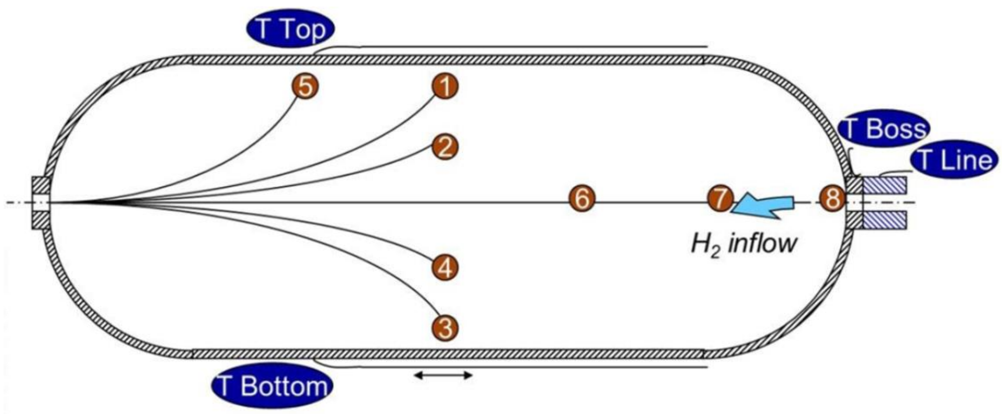

Figure 2 Experimental set up: Thermocouples inside the tank. Source: JRC

Figure 2 shows the experimental set up. In addition to thermocouples between liner and wrapping, further thermocouples are distributed inside the tank volume to identify different temperature zones and inhomogeneity's including hot spots. Test results will be used to verify and improve thermodynamic modelling.

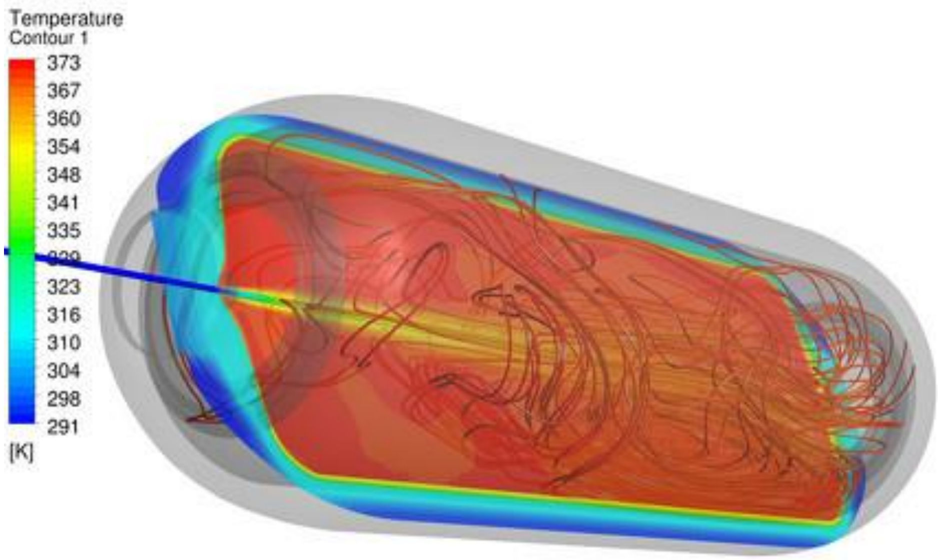

Figure 3 **Graphical example of the simulations that are being performed as part of HyTransfer. Source: JRC**

2 Work Performed since the Beginning of the Project and Main Results Achieved so far

These are the major accomplishments for the first half of the 30 month project HyTransfer:

- Tanks for experiments and modelling are selected (WP2)
- Experimental program is defined, CFD modelling identified hot and cold spot areas, a simple model is set up (WP3)
- Selected tanks were manufactured with thermocouples placed between liner and wrapping, instrumentation for experiments was defined and manufactured (WP4)
- Identification of RCS issues and recommendations to address these (WP7)

The relation between the work packages can be seen in Figure 4.

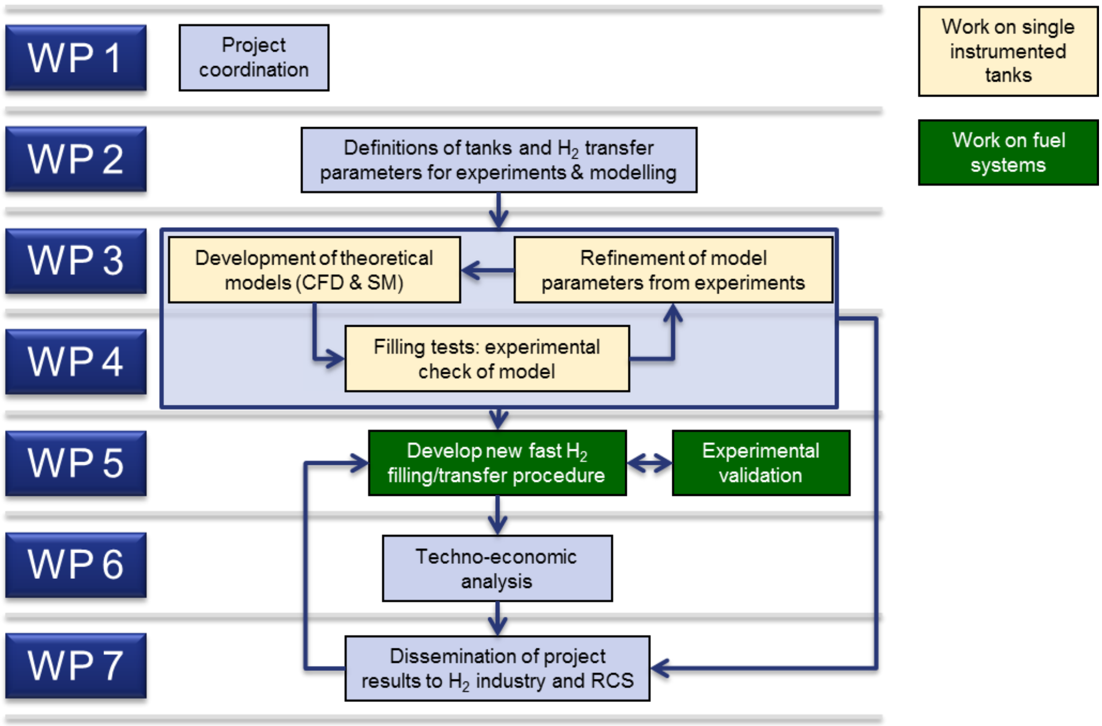

Figure 4 Workpackage structure of HyTransfer

WP2 – Description of storage and fuelling systems

One of the first steps within HyTransfer was to select a representative set of tanks that are going to be used for experiments and modelling. This was done by defining limits of tank systems and fuelling conditions and constraints in existing RCS. Three different tanks from two manufacturers were chosen: 1 large tank, two smaller ones. One of the small tanks is a type 3 tank, the other ones are type 4.

WP3 – Required temperature control measures to meet specified temperature limits

In parallel to the selection of the tanks in WP2, a literature review on the thermodynamic of filling was prepared. Based on this and the previous experience of the HyTransfer consortium, the expected hot and cold spots during filling and emptying were identified through CFD modelling, cf. Figure 5. A simple model was set up for identifying the average gas temperature and the 1D temperature profile in the tank wall during filling and emptying processes.

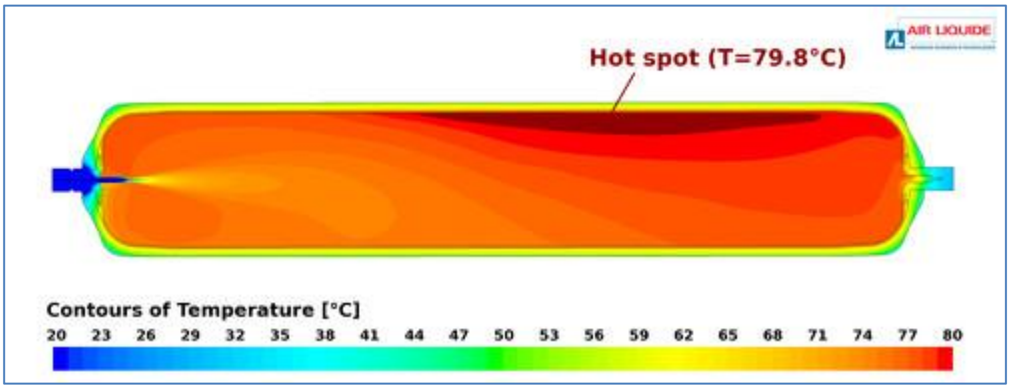

Figure 5 CFD simulation of the filling of a 531 litre hydrogen tank with hydrogen at -20°C for 25 minutes. As one result, thermocouples for recording temperature during experiments were placed according to this temperature field. Source: Air Liquide-aT / HyT 2014

WP4 – Experimental validation on single instrumented tanks

Experiments on single tanks is the core task of WP4. These experiments will take place in the second half of HyTransfer in three different labs. Most of the preparation of the experiments was performed in the first half of the project. The tanks selected in WP2 were manufactured with 30 thermocouples placed between liner and wrapping. The thermocouples were placed according to the results of the CFD modelling in WP3. Burst and cycling tests were performed to validate mechanical durability of these modified tanks to ensure safety during the main experiments. Instrumentation such as further temperature measuring devices and different kind of injectors were developed and manufactured.

WP5 – Evaluation and validation of improved approach applied in a real fuelling system

This workpackage is based on the results from WP3 and WP4 and will only start in the second half of the project.

WP6 – Techno-economic Analysis

The techno-economic analysis itself is based on the results of the previous workpackages and therefore will be performed in the second half of the project. However, continuous monitoring of global RCS developments is relevant throughout the project and was performed from the first day. This is ensured as several members of the HyTransfer consortium are members of the relevant RCS working groups. The HyTransfer brochure is e.g. a ISO/TC197 WG24 info document and therefore downloadable from their internal website.

WP7 – Recommendations for industry & RCS (Regulations, Codes, and Standards)

This workpackage consists of three parts, all three are continuously ongoing throughout the project. The first task is the preparation of recommendations for RCS. In a first step, RCS issues and recommendations on how to address these issues were identified.

The second task is dissemination. A corporate design including a logotype was developed. The project website was online three months after the beginning of the project. A flyer was prepared and posters for the International Conference on Hydrogen Safety (ICHS) in September 2013 and for the FCH JU Review Days 2013.

The third task is the formation of an Expert Networking Group (ENG) to discuss the HyTransfer content and approach with relevant stakeholders from industry and gain their input. Two meetings were hold in September and October 2014.

3 EXPECTED FINAL RESULTS AND THEIR POTENTIAL IMPACTS AND USE

Expected final results:

HyTransfer aims to develop and experimentally validate a practical approach for optimized fast filling and defueling of compressed hydrogen, meeting the material temperature limits of the tanks. The new refuelling approach will result in technical and economic benefits compared to the state-of-art. It will be relevant for fast fuelling as well as for defueling and gas transfer operations in the hydrogen supply chain.

HyTransfer will have been successful, when this new refuelling and defuelling approach is published as a recommendation to international RCS (regulations, codes, and standards) bodies.

International state of the art (SoA):

According to “SAE TIR J2601 -Fuelling protocols for Light Duty Gaseous Hydrogen Surface vehicles” for 70 MPa refuelling, pre-cooling of -40°C to -33° C is systematically required and filling time may exceed the 3 minutes target

HyTransfer target:

- Shorter refuelling and defuelling time
- Less pre-cooling
- Increased flexibility of the fuelling protocol, taking the initial conditions into account

Potential impact and use:

Having the improved criteria for temperature control of gas transfer taken up by international standards is the way to have these adopted by all stakeholders globally.

Successful uptake is insured by the participation of respected players of the sectors directly concerned in the consortium of HyTransfer (hydrogen supplier, hydrogen fuelling technology supplier, hydrogen fuel cell vehicle manufacturer, hydrogen pressure vessel manufacturer, standardization expert, testing experts) almost all of which are already very active and influential in international standardization.

Temperature control of gas transfer can be excessively costly if not optimized. As a result of HyTransfer, the hydrogen supply and refuelling infrastructure costs will be reduced, facilitating the commercial development of hydrogen energy applications.

Identifying the most cost effective solutions is essential for minimizing the cost barrier that needs to be overcome for initiating the large scale deployment of hydrogen and fuel cell technologies.

The impact of the HyTransfer approach concerning a more profitable business case for HRS will be evaluated in 2015.