First results of the french national project "Drive": experimental data for the evaluation of hydrogen risks onboard vehicles, the validation of numerical tools and the edition of guidelines

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FIRST RESULTS OF THE FRENCH NATIONAL PROJECT "DRIVE": EXPERIMENTAL DATA FOR THE EVALUATION OF HYDROGEN RISKS ONBOARD VEHICLES, THE VALIDATION OF NUMERICAL TOOLS AND THE EDITION OF GUIDELINES

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INTRODUCTION

Hydrogen has been used in many industrial and commercial applications with quite an exemplary safety record. Should it become more extensively used in the transport industry, it is thought that the existing safety procedures will provide only limited guidance for hydrogen-powered vehicles. However, automotive makers will have to ensure that this new technology is as safe as the conventional one and it is therefore important to understand in the early stage of development hydrogen behaviour on-board the vehicle in order to identify the acceptable risks and to control any hazardous risk. Since only a small number of these vehicles are in operation today, data available on safety aspects are quite limited.

BRIEF DESCRIPTION OF THE DRIVE PROJECT

This drove the National Institute of Industrial Environment and Risks (INERIS) along with the Atomic Energy Commission (CEA), the automotive manufacturer PSA PEUGEOT CITROËN and the Research Institute on Unstable Phenomena (IRPHE) to submit with success a project called DRIVE to the French National Research Agency. This is a three-year programme which started in early 2006.

In addition to its primary objective which consists in providing experimental and numerical data to better assess hazards when handling hydrogen onboard vehicles, this project will provide:

- a detailed description of all aspects of the chain reaction leading to an hydrogen risk (release → explosive atmosphere → ignition → jet fire or explosion) and the methodology to quantify them.
- a list of potential failures / consequences that could be met in a hydrogen vehicle and the best safety strategies for its design,
- the best practice recommendations for the use of CFD tools as a means to quantify hazards.

These documents will help in strengthening the risk assessments and will permit to segregate tolerable accidental releases to unaccepted ones and will propose innovative solutions for the handling of hydrogen in cars compatible with a public use.

FIRST RESULTS OF THE PROJECT

Release quantification

Hydrogen releases can be classified into three categories:

- **Accidental releases**: they arise from a single system dysfunction or rupture of one of the components (pipe). They could result in massive H_2 release (from 10^1-10^2 cm^3/s) but are associated with a very low probability of occurrence. By assuming that hydrogen behaves like a perfect gas (which is not true when the driving pressure is above 50-100 bars), some means of calculating the released mass flow can be found in Tchouvelev et al (2007).
- **Permeation-type releases**: they are inherent of the system and depend on the material through which hydrogen diffuses. These leaks are usually so low (on the order of 10^{-2}-10^{-3} cm^3/s) that they can not create any explosive atmosphere within a confined environment. Some indications regarding the calculation of permeation-type leaking rate are given by Schefer et al (2006) or San Marci et al (2007).
- **Chronic releases**: these releases come from components and connections and are expected to be as low as permeation-type releases. These chronic releases mightincrease because of vehicle ageing (worn seal, damaged component) or bad maintenance (loose fitting, succession of clamping / unclamping operations…). In this case, it can be managed as any accidental release with the same safety procedures.

The task I.1.2 of the DRIVE project consisted in measuring the chronic hydrogen releases from key components of the hydrogen vehicle (valves, connectors, pumps...). Each component was placed within a 50 L chamber, which was entirely sealed and thermally insulated, and then fed with hydrogen at different pressures: from few bars for a component normally located close to the conversion system and up to 700 bars for one in the storage area. Any release arising from this component resulted in a pressure rise within the chamber more or less important depending on the volume of hydrogen released. It is worth noting that oil was also present in the lower part of the chamber. This was made to adjust the free volume surrounding the component and thus improved the accuracy of the measurements.

Besides being able to quantify precisely the hydrogen release, it is equally important to look at how hydrogen disperses into its environment so as to be able to estimate the dimensions of the resulting explosive atmosphere.

Hydrogen dispersion...

... in a free environment

The task I.2.3 was aimed at gaining further understanding regarding the dispersion of a high-pressure release in a free and obstructed environment. Hydrogen was replaced by a non-reactive gas during all these tests.

The preliminary tests were performed by releasing air or helium in a free environment through a 1, 2 or 3 mm orifice and with a pressure varying in the range 2–8 bars. The investigation was particularly focused on the compressible effects taking place in the near field region of the underexpanded axisymmetric jet. The location and diameter of the Mach disc were determined by means of the Background Oriented Schlieren (BOS) technique and the data were found to be in relatively good agreement with the available literature. Further tests are scheduled with a release pressure increased up to 150-200 bars and the effect of obstacles of different size and shape will also be studied.

... within a confined environment

A hydrogen release occurring on a vehicle parked in a confined space is a situation where it is important to fully understand all the mechanisms leading to the build-up of a potentially explosive hydrogen-air mixture. This was achieved by the task I.2.2 of the DRIVE project.

The facility was based around a rectangular box representative of a single-vehicle private garage. The garage had internal dimensions of 5.76 × 2.96 × 2.42 m and was fitted with a commercial tilting door at the front and a technical access door at the back. All the walls were made up of panels joined together by means of an aluminium seal tape. This structure prevented any leakage from the garage (at least during the test duration) but could not withstand high overpressures. Consequently, there was a 200 mm diameter opening at the bottom of the back wall to ensure that the garage will be kept at atmospheric pressure throughout the release. At the end of the release, this opening was sealed to investigate the gas dispersion within the garage.

Fig. 1: Picture of the garage and the fuel cell vehicle

Again, the experiments were conducted with helium rather than with hydrogen and, at the beginning, with no vehicle in the garage. The concentration, whose distribution was found to be strongly three-dimensional during the release, rapidly stratified and increased with the height. It was interesting to note that most of the gradient took place in the upper half of the garage. The effects of various parameters (released flow rate, volume and direction) on the characteristics of the explosive atmosphere were also looked at during these tests.

Hydrogen combustion and explosion

Further tests are currently under way within the task II.2.3 of DRIVE to quantify the thermal effects associated with the release of ignited hydrogen jets from a reservoir pressurized at 700 bar max.

CONCLUSIONS

Innovation and new technologies often brings new risks that have to be assessed. Only some vehicles are in operation today and that limits quite significantly the data available on safety aspects. The DRIVE project is intended to provide both experimental and numerical data on that subject and WHEC 2008 is a good opportunity to share with the scientific and industrial committee its first outcomes.

ACKNOWLEDGMENTS

Author would like to thank the French National Research Agency ANR and particularly its hydrogen programme PAN-H which supports financially this project.

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BRIEF BIOGRAPHY OF PRESENTER

Olivier Gentilhomme gained his PhD in Mechanical Engineering (2003) at the University of Sussex in Brighton (UK). From 2004 to 2006, he worked for the consultant company Teuchos Exploitation, which is part of the Safran group, and carried out numerical simulations for the car manufacturer Renault. He is currently working at INERIS (French National Institute of Industrial Environment and Risks) where he is conducting risk analysis for industrial facilities and developing codes for cloud dispersion in free and/or confined environments.