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Review

Large-scale hydrogen release in an isothermal confined area

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ABSTRACT

INERIS has set up large-scale fully instrumented experiments to study the formation of flammable clouds resulting from a finite duration leakage of hydrogen in a quiescent room (80 m^3 chamber). Concentration, temperature and mass flow measurements were monitored during the release period and several hours after. Experiments were carried out for mass flow rates ranging from 0.2 g/s to 1 g/s. The instrumentation allowed the observation and quantification of rich hydrogen layers stratification effects. This paper presents both the experimental facility and the test results. These experimental results have been used to assess and benchmark CFD tools capabilities [1].

1. Introduction

In a medium term future, one could expect an increasing number of hydrogen energy systems to be operated or stored (moving applications) inside buildings (dwellings, garages,...). Whereas outside location would be preferable in most cases to prevent leaking hydrogen from accumulating, inside location will remain in many cases a necessity although moderate releases of hydrogen in confined or semi-confined geometry is known to present a serious risk since combustible mixtures may form. Literature is rather poor on that critical subject [2–7] to permit a robust analysis and to develop a predictive quantification model or a safety standard development. Furthermore in many experimental studies helium is used as a tracing gas rather than hydrogen.

In order to better understand how hydrogen behaves when released in confined space and especially to assess in which circumstances explosive mixtures may form and how long it may take to dissipate, INERIS has set up large-scale fully instrumented experiments to study the mechanisms of the build up and dispersion of flammable hydrogen/air clouds resulting from a finite duration subsonic leakage in a quiescent isothermal room followed by a long observation time in similar conditions.

Concentration, temperature and mass flow measurements were monitored during the release period and several hours after in order to investigate the diffusion process.

The objective of this paper is to provide consistent experimental results on hydrogen release in large-scale closed and quiescent volume for a moderate but realistic leakage. These results will help to better understand and assess small hydrogen releases consequences in closed area and therefore contribute to better conduct risk assessment and take appropriate control measures.

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Fig. 1 – General view of the experimental set up environment.

In the following section 2 a detailed description of the experimental test facility is given. Hydrogen and helium concentrations evolutions during convection and diffusive phases are presented and discussed in Section 3. Finally conclusions are drawn in last section.

2. Test facility description

2.1. Chamber

Experiments were performed in a 80 m^3 chamber built inside a rock gallery (Fig. 1). This chamber has the shape of a rectangular box, see Fig. 2 with average dimensions 7.2 × 3.78 × 2.88 m in length, width and height respectively. The room ceiling and the front side are made up of wood and plastic sheeting, whereas the ground has a negligible slope in the length and width directions. The rock solid mass ensures a thermal stability of the inner and prevents any convection effect.

The walls are closed and tight except the front side that accommodates 3 holes (Fig. 2). The bigger one, which is referred to as "opening 1" in the Fig. 2, has a diameter of 0.15 m and is located at the top. The goal is, for safety reasons, to ventilate the chamber between the experiments. There are two other smaller openings, named as "openings 2 & 3" in the Fig. 2. They are 0.05 m in diameter and were used to pass on the electrical cables. During all the experiments, these holes were kept closed unless otherwise specified.

The left, right and bottom sides are not smooth surfaces; the roughness size on those surfaces is between 5 mm and 10 mm (Fig. 3).

2.2. *Mass flow control*

The hydrogen mass flow rate is controlled by a home-made system based on the chocked flow principle. Above a given upstream pressure, the exit velocity at the orifice is constant and equal to the speed of sound of the leaking gas, known as sonic release. Under these conditions, and for a given orifice, the desired mass flow rate can be obtained by adjusting the upstream pressure by means of the gate valves V1 & V2 in Fig. 5. Correlation between upstream pressure and mass flow rate has been undertaken before the operation. For the purpose of calibration, (see Fig. 5), the mass flow control set up (left tank up to sonic nozzle) is associated to the calibration apparatus (right hand side equipment after sonic nozzle).

Sonic openings with different diameters generated hydrogen flow rates between 5 mg/s and 10 g/s with an accuracy of ±2%.

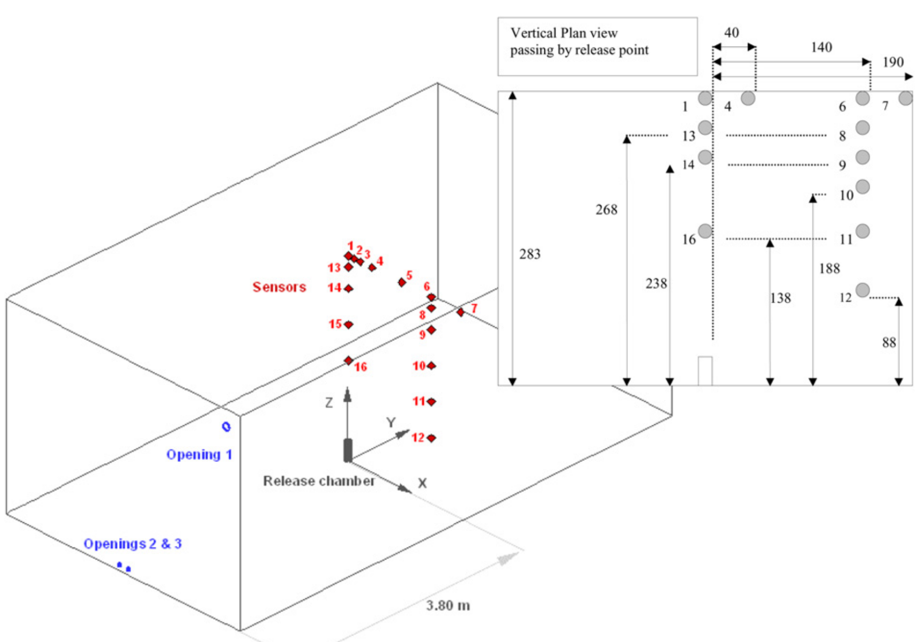

Fig. 2 – Release chamber scheme and sensor positions; vertical plan view passing by release point and twelve points of measurements.