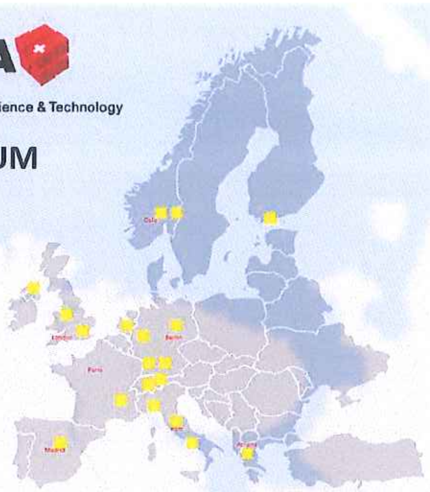
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

EMPA Materials Science & Technology

H2FC EUROPEAN RESEARCH INFRASTRUCTURE

9th INTERNATIONAL SYMPOSIUM HYDROGEN & ENERGY



Integrating European Infrastructure to support and development of Hydrogen- and Fuel Cell Technologies towards European Strategy for Sustainable, Competitive and Secure Energy

www.H2FC.eu

CHARACTERISATION OF HIGH PRESSURE HYDROGEN RELEASE FLAMMABILITY PROFILES CLOSE TO THE GROUND

HALL J., O'SULLIVAN L., HOOKER P., ANGERS B. (1), BENARD P. (1)

Health and Safety Lab

Harpur Hill, Buxton, SK17 9JN, United Kingdom

Hydrogen Research Institute (1)

3351, boul. des Forges, C.P. 500, Trois-Rivières (Québec) , Canada, G9A 5H7

INTRODUCTION

The presence of surfaces affect the dispersion behaviour of jets, impacting the flammable extent of combustible gases. The importance of the effect will depend on the distance between the orifice and the surface, on the momentum of the jet and the buoyant forces. In addition, the presence of the surface will affect turbulence, induce recirculation zones and may result in a Coanda effect. Through their effect on the flammable extent, surfaces can directly impact risk analysis and thus require a thorough understanding.

OBJECTIVES

- To study the properties of unignited high-pressure hydrogen jets close to surfaces
- To study the influence of surfaces on ignited high-pressure hydrogen releases
- To generate experimental data to validate CFD modelling

EXPERIMENTS PERFORMED

Four separate experimental test series have been performed consisting of unignited (series 1, 3) and ignited (series 2, 4) experiments of high pressure H_2 jet releases close to the ground and close to a ceiling. For each series, six configurations were tested. Three measurements were performed on every configuration. Two nozzle sizes were used. The storage pressure was adjusted to result in similar LFL extents (Table 1).

Table 1. Test conditions for unignited and ignited releases of high pressure hydrogen close to the ground and close to the ceilings.

Test Storage Pressure (barg)	Orifice Size (mm)	Series 1-2									Series 3-4					
		Distance from ground (m)									Distance from ceiling (m)					
		0.05			0.48			1.22			0.08			0.49		
150	1.06	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6
425	0.64	10	11	12	13	14	15	16	17	18	10	11	12	13	14	15

For the unignited releases, hydrogen concentration was measured at 4 points per run using thermal conductivity sensors with a working range of 0 to 100% v/v hydrogen. For the ignited releases, three radiometers (maximum range 110 kW/m^2) were used to measure radiant heat flux at various distances from the jet and an IR camera to visualise the ignited jet. A single ignition location was used for each flow condition.

SIMULATION PERFORMED

For the CFD modelling, fifteen unignited jets close to the ground and one jet close to the ceiling were modelled with FLACS (Figure 1) using the flow and ambient conditions prevailing at the moment of each corresponding experiment. Average wind velocity and average wind direction were used. To quantify the effect of the wind on the results, free jet releases at 150 barg and 425 barg, as well as an attached jet release close to a ceiling at 425 barg were modelled without wind. One axisymmetric vertical jet at 150 barg was also modelled with Fluent using the RNG k-ε turbulence model.

Figure 1.Test facility (left), FLACS geometry (right)

RESULTS AND CONCLUSION

From an experimental aspect there appears to be a distinction between releases of hydrogen close to the ground or close to a ceiling surface when compared with free releases (Figure 2 and 4). This has implications for the wider use of hydrogen in the automotive and energy sectors. There are also other correlations that can be deduced from the tests performed.

From a CFD aspect, the experiments were carried out in highly unstable windy conditions such as time dependent directions and velocities which cannot be set accurately in the CFD tool. The wind greatly affects the concentration profile of the jets (Figure 3). Compared to experiments, the CFD simulations over-predict the extent of jets in most cases (Figure 2). This has implications for the use of CFD tools to predict the behavior of hydrogen releases close to surfaces in the presence of highly unstable wind.

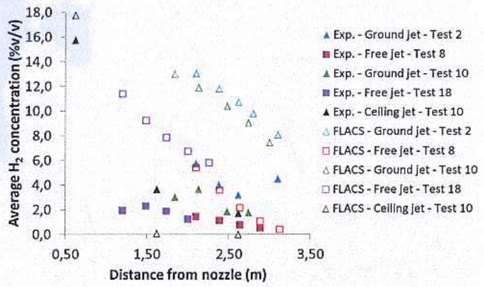


Figure 2. Average H_2 concentration for free jets, ground releases and ceiling releases from series 1 and 3

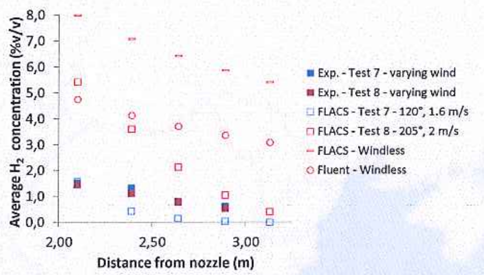


Figure 3. Average H_2 concentration for test 7 and 8 and for corresponding free jet simulations without wind

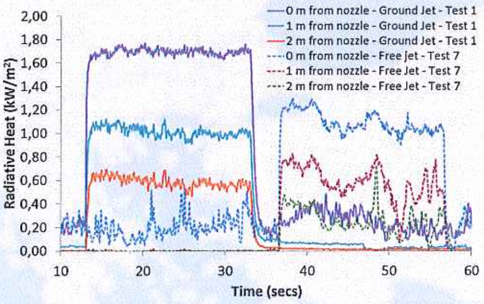


Figure 4. Experimental radiative heat flux downstream from nozzle for Test 1 and 7, Series 2, 2 m from release

This project became indirectly funded through European Commission by occupying transnational access of H2FC European Infrastructure which is funded by FP7 Capacity Program, Grand Agreement no. FP7-284522

cea · EMPA · Pro-Science · BAM · VTT · Università di Pisa · Paul Scherrer Institut PSI · Università degli Studi di Perugia · SINTEF · KIT · ENEA · Health & Safety Laboratory · NPL · IFE Institute for Energy Technology · University of Ulster · Jülich · tecnalia · JRC · CAPACITIES