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Behaviour of hydrogen jet releases close to surfaces

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Understanding the behavior of potential surface jets for hydrogen safety is important as proximity to a surface may affect the chances of an ignition event to occur by increasing the flammable volume. This may have consequences for hazard analysis, for instance if it is assumed that flash fires are 100% lethal within the flammable envelope. Furthermore, assumptions made about the location of sensors, the definition of exclusion zones, etc. based on the classical scaling laws may not be valid.

Typically, if the release orifice is close enough to a surface, the flammable extent of releases will be increased. The proximity of jets to surfaces will modify the scaling behavior of expanded jet and typically increase their flammable lengths, which can be defined as the distance from the nozzle to the point where the concentration field drops to the lower flammability limit (4% by volume for hydrogen). They may induce a Coanda effect, create a recirculation zone between the nozzle and the surface, and generate transient behavior such as puffing, which may temporarily increase the flammable extent beyond the steady state equilibrium concentration profile for a short while after the release is initiated. The properties of attached jets have been studied numerically, and to a lesser extent experimentally for unignited and ignited releases. Simulations performed using FLACS , have been performed to examine the overall behavior of hydrogen and methane jets over wide ranges of pressures (100-700 bars). An interesting behavior was observed for the normalized overextent of the flammable distance from the nozzle induced by the presence of the surface when expressed as a function of a normalized distance of the orifice from the surface. Because of the simple modeling assumptions that were used to enable the study of the wide range of conditions and the number of distances of the orifice to the surface, these results require experimental confirmation and cross-checking with simulation results obtained using more complex turbulence modeling. Obtaining experimental data covering a wide variety of release conditions (of relevance to current applications using for instance pipes close to surfaces or hydrogen in enclosed environment such as warehouses or mines) would therefore be highly valuable.

Objective :

The objective of this project is to validate the numerical simulation work performed so far describing the effect of the proximity to surfaces on the flammable extent of an unignited jet release as a function of distance and on its properties (thermal radiation, flame length and overpressure) after ignition.

Methodology:

The project will involve performing experiments of quasi-stationary jets as a function of the distance to a surface whose normal is perpendicular to the axis of the jet. The effect of the nature of a surface would also be studied. The maximum flammable extent of the jet along the centerline and the ground will be measured as a function of the distance between the surface and the orifice. The jet properties will be determined in collaboration with the experimentalists, in such a way as to reproduce the main features of the simulated behavior summarized the two references cited below.

We propose two configurations for validation experiments: (1) a horizontal jet close to the floor (2) a horizontal hydrogen jet close to a vertical wall parallel to the axis of the jet. The set-up should allow for a systematic variation of the proximity to these surfaces.

The flow rates that can be tested will be determined by the experimental limitations, which are (a) the size of the facility and (b) the ability to simulate a more or less a steady-state release. Note that numerical simulations could be performed by UQTR to account for a time-dependent release if it is needed.

The experiments could be performed using orifices of 8.48 mm at 284-barg and 6.35 mm at pressures ranging from 100 to 700 bars (mass flow rates 168g/sec to 1176 g/sec). Ideally, the experiments should be performed at constant pressure in the storage units. The experimental conditions can be changed if needed to meet experimental constraints using the scaling functions obtained from the numerical studies detailed in the references cited below.

The experiments would require the use of small (micro-machined) sensors or other non-interfering methods (like Raleigh scattering or BOS) to measure the concentration profile along the axis of the jets, on the ground and along the centerline defined by the orifice of the release. The time dependent concentration measurements would be recorded to examine transient effects and to perform a time average of the concentration data once the jet is stabilized and becomes stationary.

For each height, the jet would then be ignited at different locations of the centerline and the shape of the jet flame and its thermal radiation would be filmed to perform time-averages. The effect of the nature of the surface would be studied.

Small scale experiments using PVI and concentration measurements would be performed by the proponents to study in details the effect of the surface on the velocity field and how this correlates to the concentration profiles.

The overpressure would be recorded if large enough jets can be realized experimentally.

Note that INERIS is currently doing methane jet release studies close to surfaces and since the experimental set-up is already available it may be cost-effective to use their facility.