Delayed Ignition Overpressure Scenarios

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There are two distinctly different scenarios that create overpressure from an external release of hydrogen into an ambient air environment:

1. Delayed ignition from a pressurized release

   While immediate ignition of a pressurized release results in a jet fire with thermal radiation and the potential for fire spread, very little overpressure develops. However, if ignition occurs after the turbulent release has developed, significant overpressure can result. This is a result of the deflagration propagating through the highly turbulent flammable mixture. Cirrone et. al. (2022) conducted experiments to study the potential overpressure associated with the delayed ignition of highly turbulent, under-expanded hydrogen jets. The data spanned a range of supply pressures: 0.5 - 65 MPA (73 – 9400 psi) and nozzle diameters: 0.5 – 52.5 mm (0.020 – 2.07 in). Ignition delays ranged from 120 ms to 20.45 seconds. The results indicate that blast waves delayed ignition from these pressurized releases are capable of bodily harm and property damage. For example, a 65 MPa (9400 psi) release with a 10 mm (0.394 in) orifice produced 20 kPa (2.9 psi) overpressure 4 m (13 ft) away. The threshold for serious bodily injury is approximately 16.5 kPa (2.4 psi). In general, the magnitude of overpressure is primarily a function of stored pressure, orifice or hole diameter, and ignition delay. For many ignited release scenarios, thermal flux will be the limiting factor; however, for large releases which ignite after a delay, blast overpressure should dictate the distance for no injury/no damage. The blast overpressure should be considered when establishing safe setback distances from equipment and vent outlets.

2. Delayed ignition of a flammable gas cloud

   If a volume of pre-mixed hydrogen and air ignite at ambient pressure in the absence of confinement or congestion a flash fire will result. Overpressure from a flash fire is low – just 1.5x incident pressure with laminar burning less than 3 m/s. However, when the open-air deflagration propagates through congestion (e.g. closely packed equipment, pipe racks, vaporizers, etc.) or reflects against barriers, overpressure which is capable of bodily harm and equipment / building damage may result. Similar to scenario 1, the cause for increased overpressure is directly related to flame acceleration due to turbulence.