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Tunnel du Mortier June 2021

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EXPLOSION PROGRAMME

Test matrix done by CEA

EXPLOSION

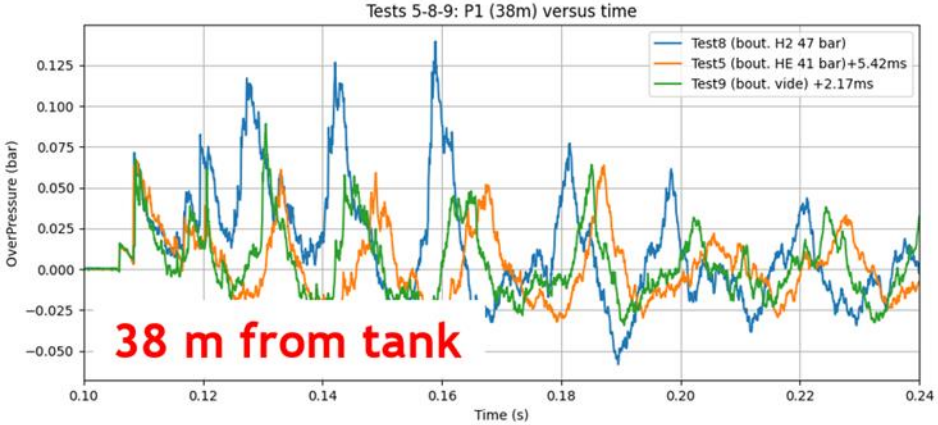
Leak no burst technology tanks

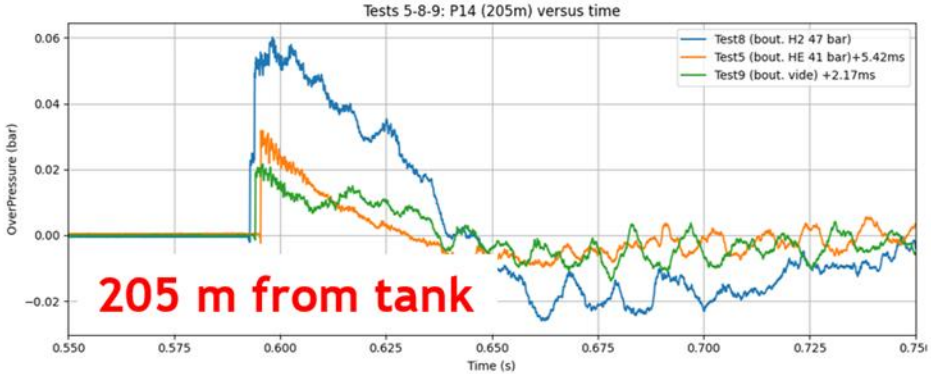
Effect of intentional rupture of a tank

Test N°	Tank	Gas	Pressure (bar)	Detonation belt charge (g, TNT)	Temperature, °C
31	TYPE II (frag.)			130	
33	TYPE IV (frag.)			228	
30	TYPE II	He	185	130	15
34	TYPE IV	He	650	228	15
32	TYPE IV	H2	90	228	15
42	TYPE II	H2	194	130	15
37	TYPE IV	H2	520	221	15
38	TYPE IV	H2	610	228	15
35	TYPE IV	H2	580	NA	NA

EXPLOSION PROGRAMME

Studied cases





- Three cases:
  GH2, **GHe**, **Detonation belt alone.**
- Similar overpressure:
  GHe and **Detonation belt.**
- Significant contribution of chemical energy from **GH2** combustion to blast wave.

EXPLOSION PROGRAMME

Overpressure study

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Full-scale tunnel experiments: Blast wave and fireball evolution following hydrogen tank rupture

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HIGHLIGHTS

- Tank rupture tests are conducted in a full-scale tunnel.
- Compressed helium tanks as well as compressed hydrogen tanks are opened with detonation belts.
- Blast wave evolution with time and distance is analyzed and compared to available correlations.
- Fireball evolution inside tunnel cross-section is filmed and analyzed.

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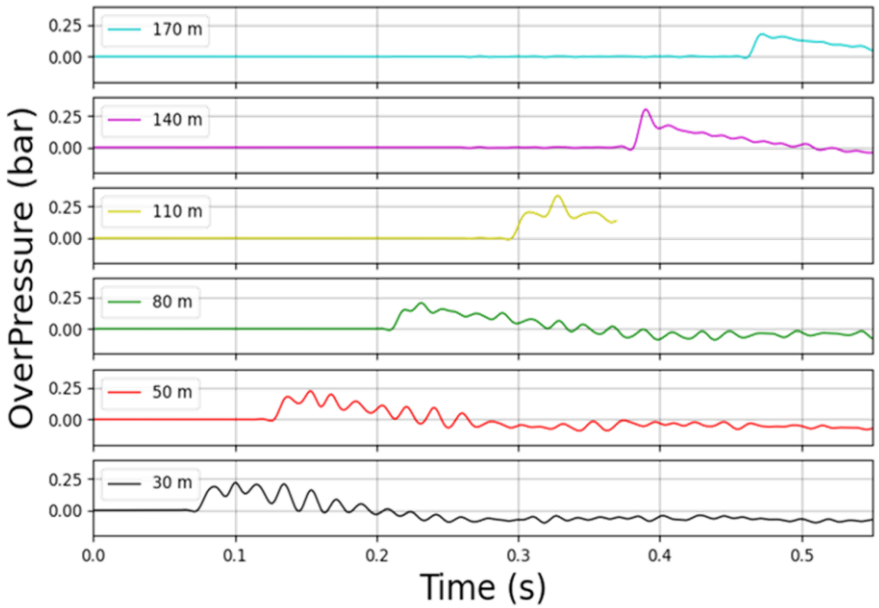
ABSTRACT

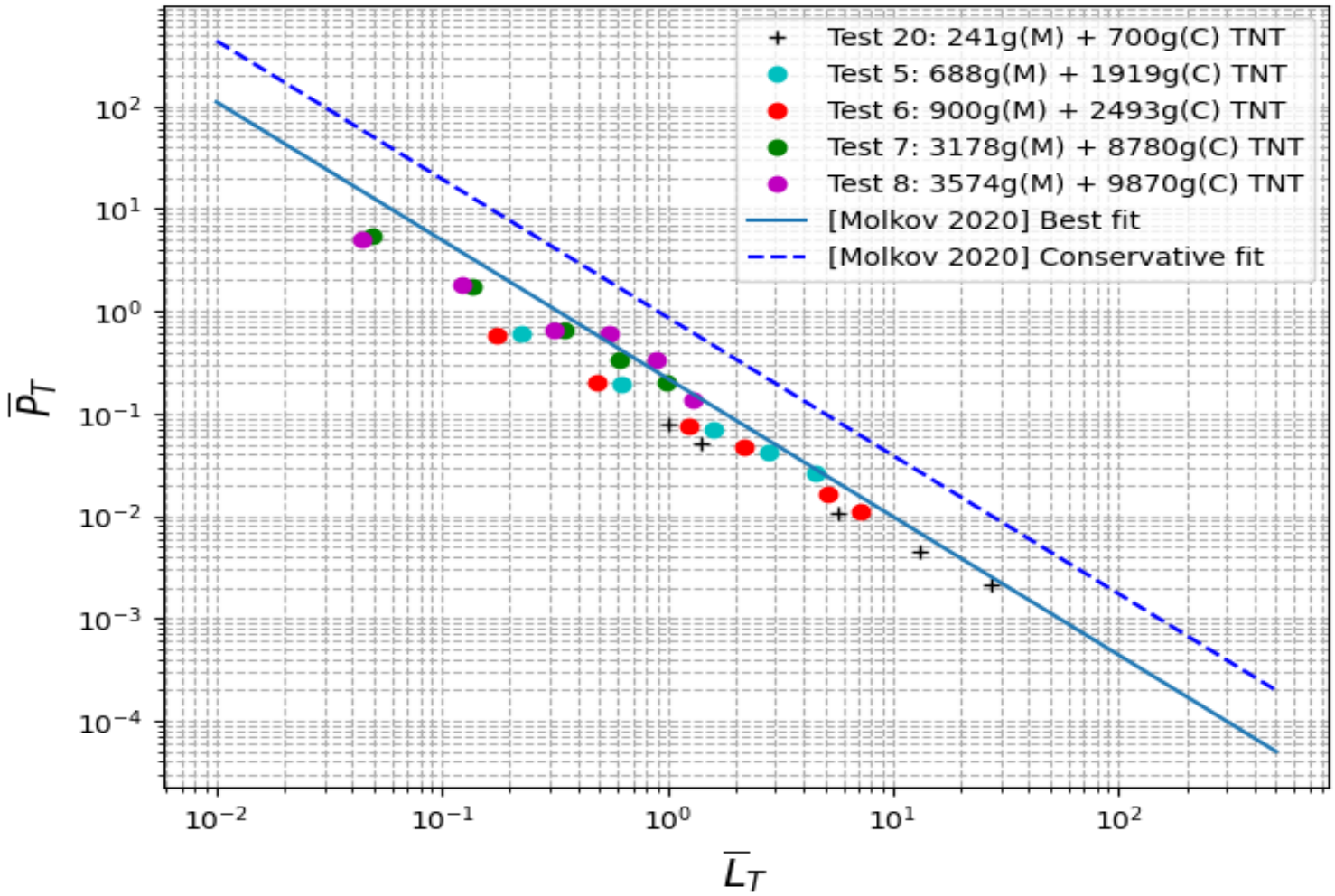
In the framework of the HyTunnel-CS European project sponsored by Clean Hydrogen Joint Undertaking (CH JU), a number of tests were conducted in a full-scale tunnel in France. These tests are devoted to safety of hydrogen-fuelled vehicles having a compressed gas storage. The goal of the study is to develop recommendations for Regulations, Codes and Standards (RCS) for inherently safer use of hydrogen vehicles in enclosed transportation systems. Two sets of tests have been performed, (a) five tests with compressed hydrogen tanks, (b) two tests with compressed helium tanks. The hydrogen gas pressure varied between 47 bar and 610 bar. The blast wave overpressures are recorded together with fireball characteristics. The obtained experimental data are compared to existing engineering correlations and it is confirmed that not only the mechanical energy of compressed gas but also a fraction of chemical energy contribute to the blast wave strength.

Figure 3 : Tanks used for explosion experiments: TYPE II (left) and TYPE IV (right). The detonation belt is attached to each of the tanks.



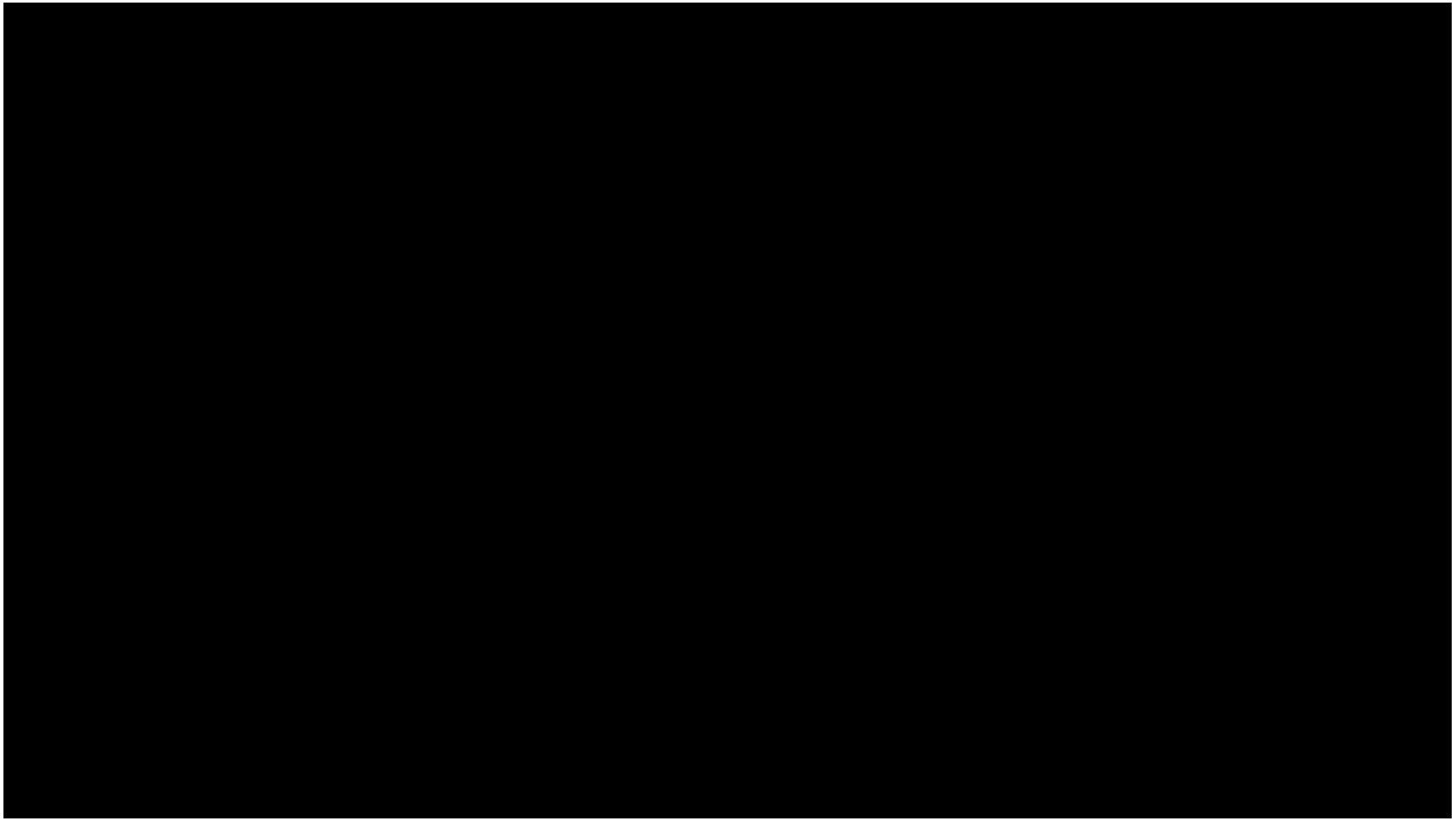
Evolution of the pressure at different distances from the explosion
Type IV H2 tank of 78L at 700bar

Comparisons with models

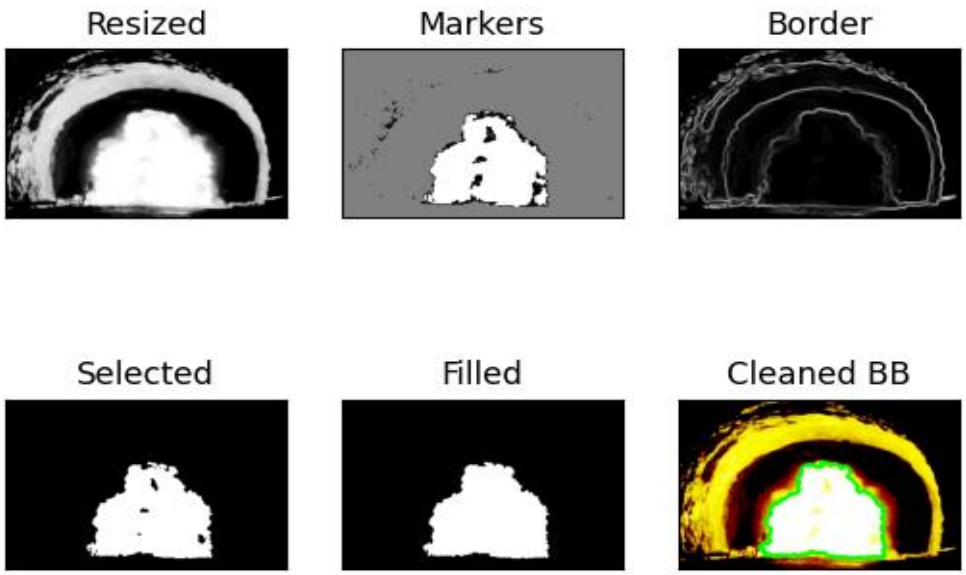


Comparison of experimental data with universal correlation. Second peak of pressure is taken into account.

Film explosion



Fireball monitoring

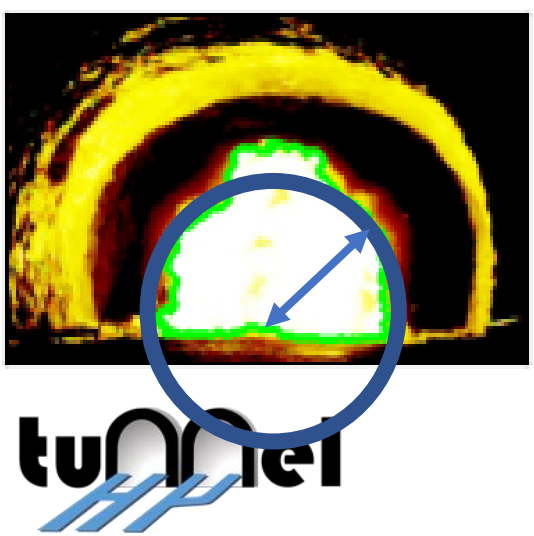


Video Analysis:
2D analysis - Surface and hemispherical radius versus time

Objectives:
Comparizon with openspace situations

$R_{hemisphere}$=9,75 $m_{H2}^{1/3}$
Makarov et al. 2021

$R_{hemisphere}$~5 $m_{H2}^{1/3}$ t=0,47 $m_{H2}^{1/3}$ conv. dominated and t=2,6 $m_{H2}^{1/6}$ buoyancy dominated
Zalosh et al. 2005



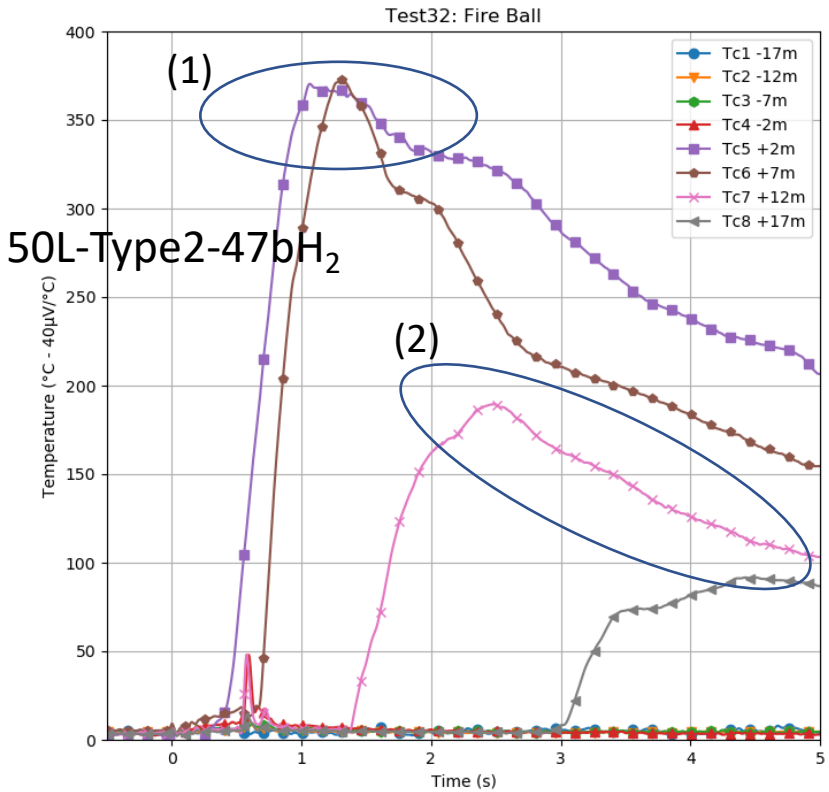
Volume	Pressure (bar)	Mass H_2 (kg)	$R_{hem.}$ (m)	t (s)	Test n°
50	194	0.725	4.5 - 8.8	0.4 – 2.5	n°42
78	90	0.558	4.1 - 8.1	0.4 – 2.4	n°32
	520	2.554	6.9 - 13.4	0.6 – 3.0	n°37
	580				n°35
	610	2.871	7.1 - 13.9	0.7 – 3.1	n°38
150	332	3.338	7.6 - 14.8	0.7 – 3.2	n°36
350	162				n°39

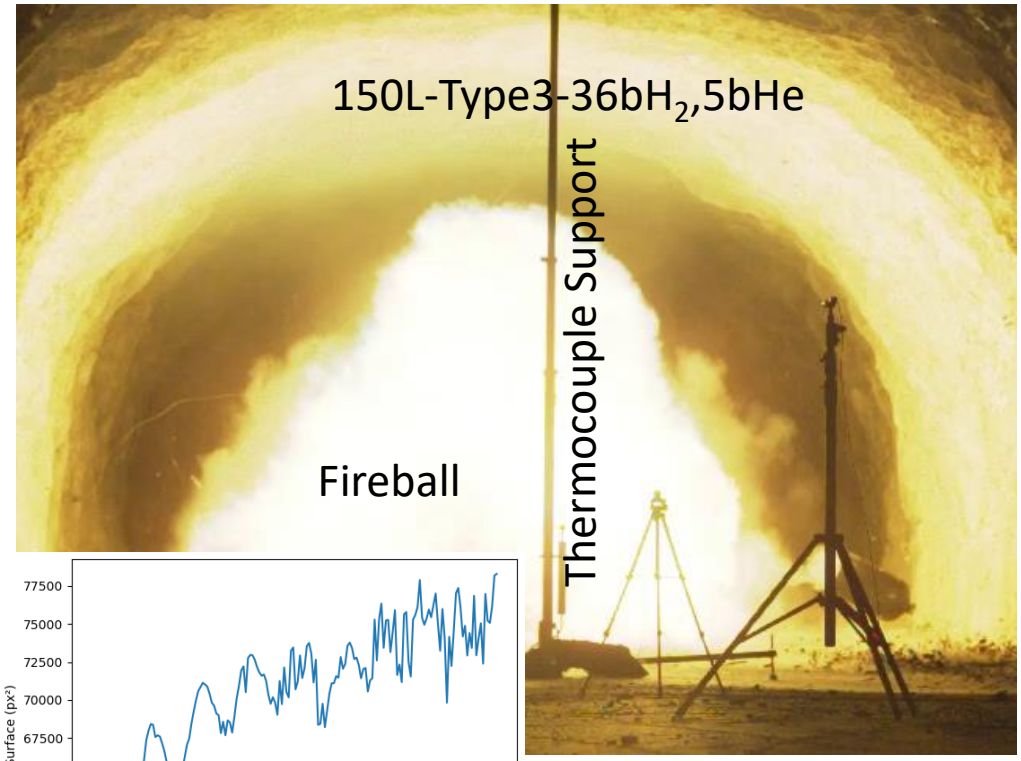
Explosion and Fireball Tests

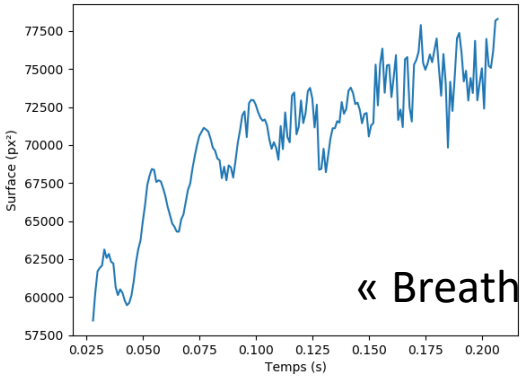
Preliminary Results 2020

(1) Fireball propagation along the ceiling ~25 m/s

(2) Hot gases convection & dilution by wind ~3.5 m/s

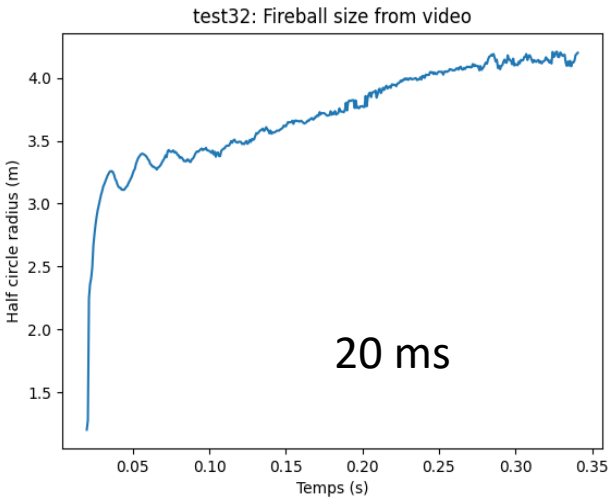


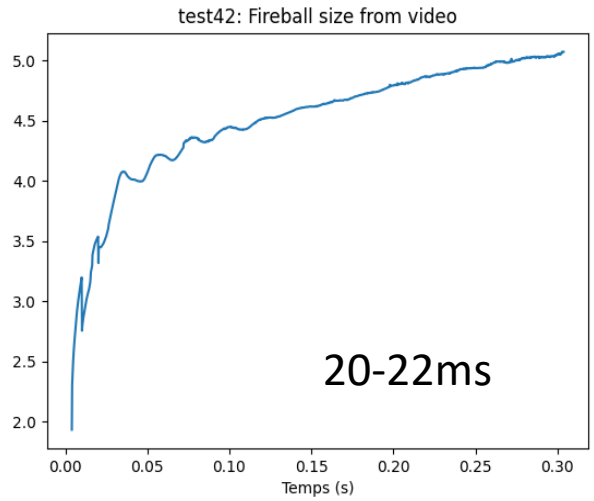




« Breathing » 25 ms

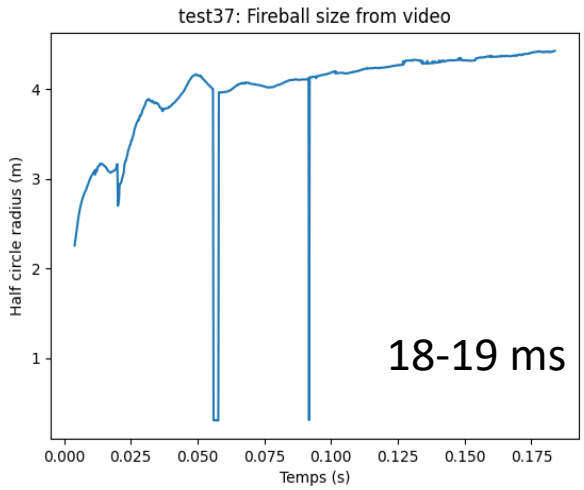
Fireball behaviour Size

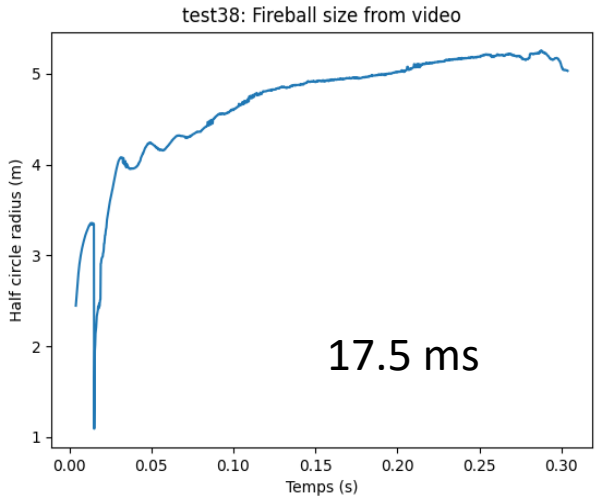


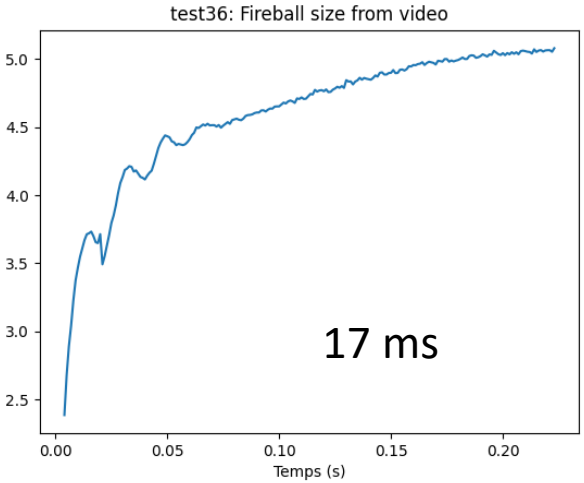


« breathing » characteristic timescale

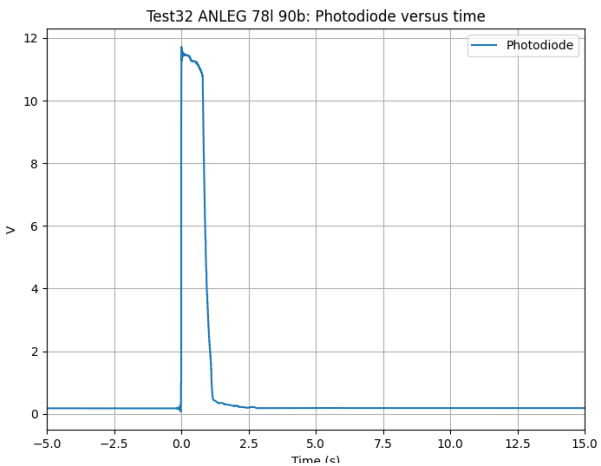
Tests 38, 36: max radius = Tunnel size

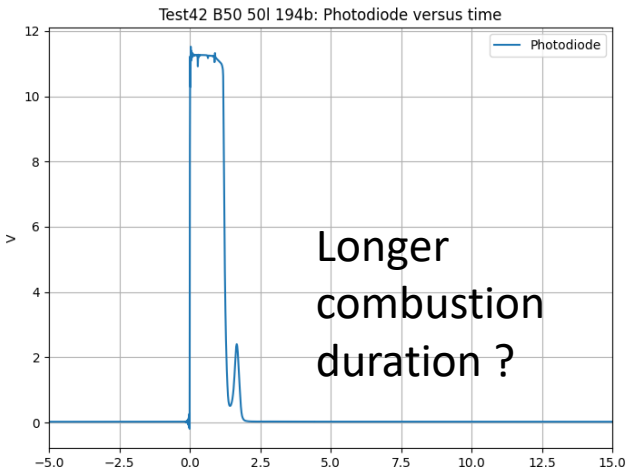




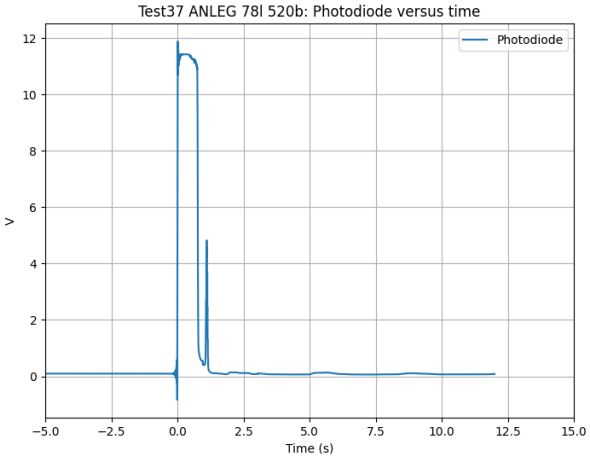


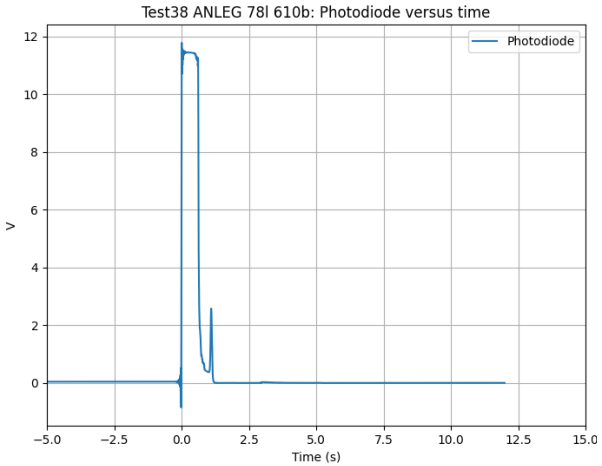
Fireball behaviour Photodiod

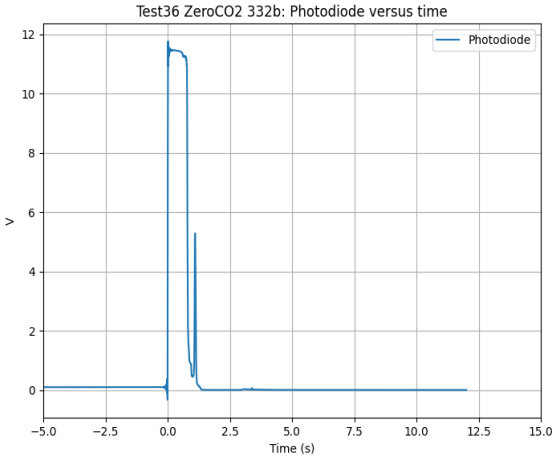




Combustion duration
Second pic = reignition

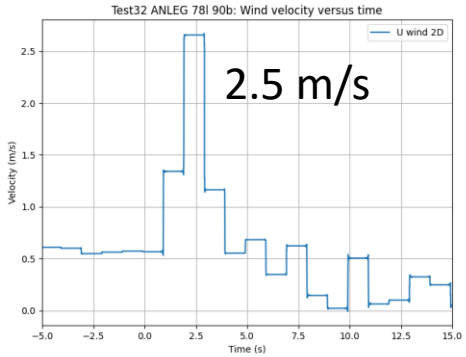


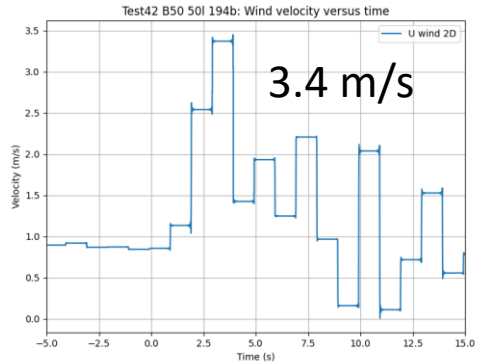


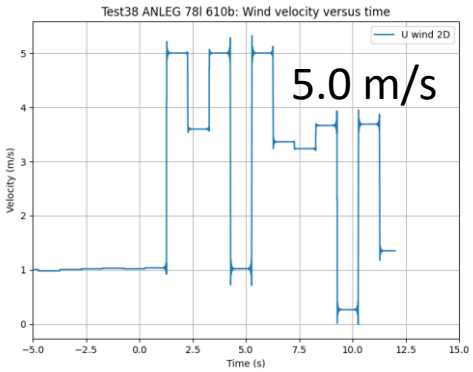


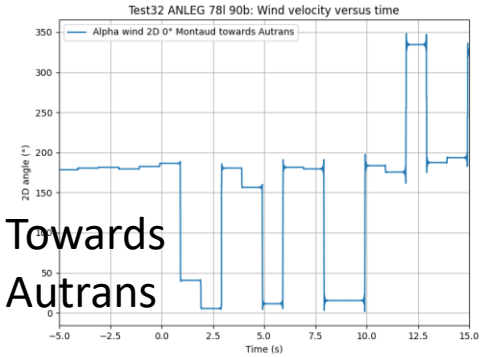
Fireball behaviour

Wind velocity and Direction

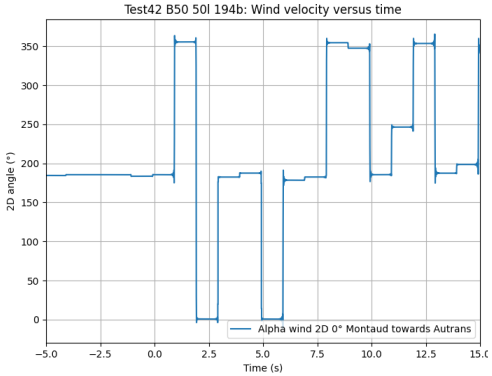


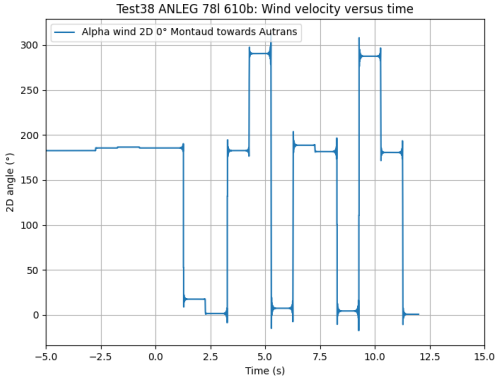






Towards Autrans





Test 32 Test 42 Test 38

Oscillatory behaviour = Multiple reflections

Conclusion

- explosion :
  - best estimate Molkov et al. conservative
  - Good fireball size prediction
  - 10% of H2 energy contributes to shock pressure
- Slow pressure decay
- Results available on portal

https://hytunnel.net/

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