THE ROLE OF THE FLOW FIELD GENERATED BY THE VENTING PROCESS ON THE PRESSURE TIME HISTORY OF A VENTED DEFLAGRATION

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PERTURBATIONS

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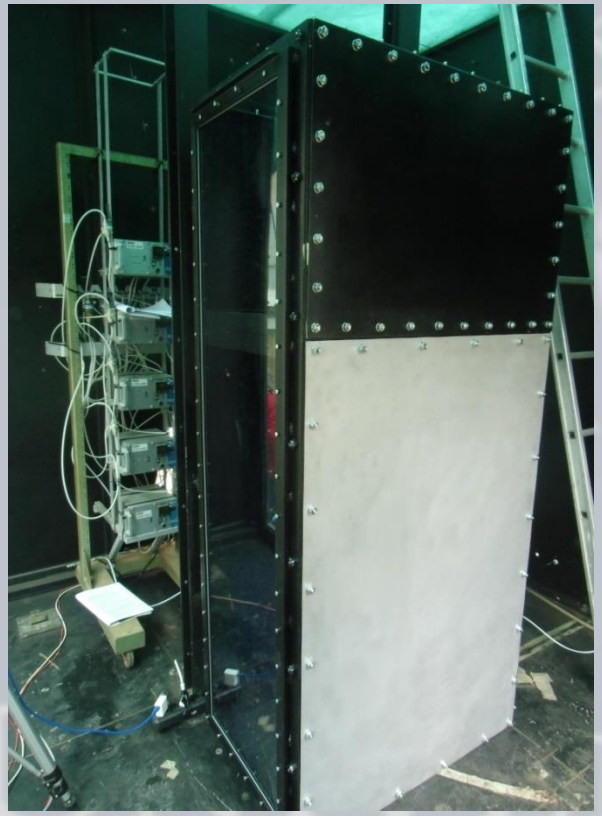
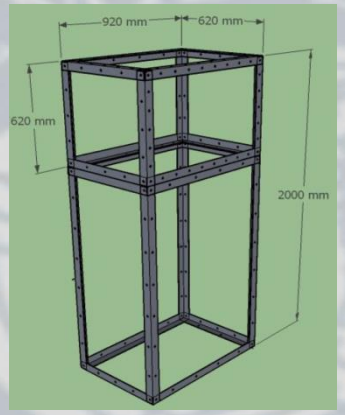
Presentation overview:

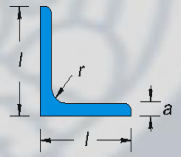
- Experimental set-up (video recording)
- Perturbation originated by the two pivotal moments in vented deflagrations:
  - Vent opening
  - Flame front reaching the vent

Experimental set-up





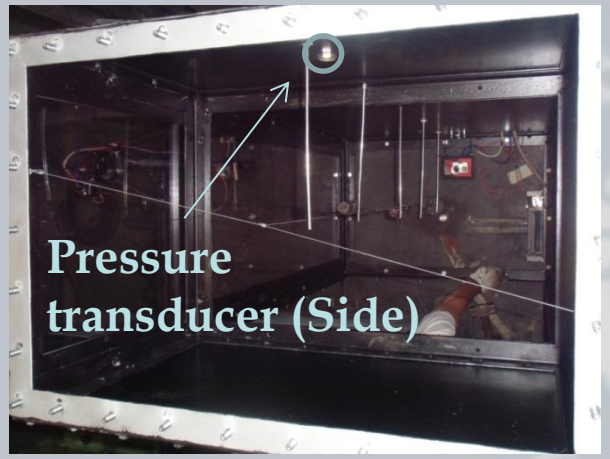
Height – 2000 mm
Width – 920 mm
Depth – 620 mm



l = 50 mm
a = 4 mm

Vent dimensions
b = 500 mm
c = 800 mm

Experimental set-up

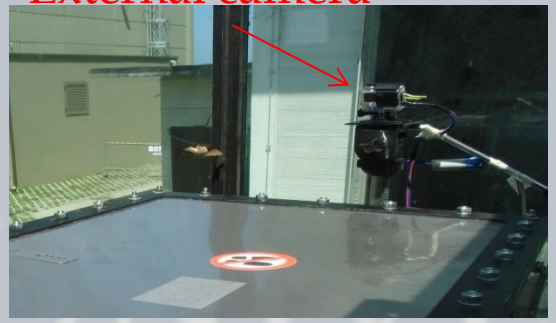


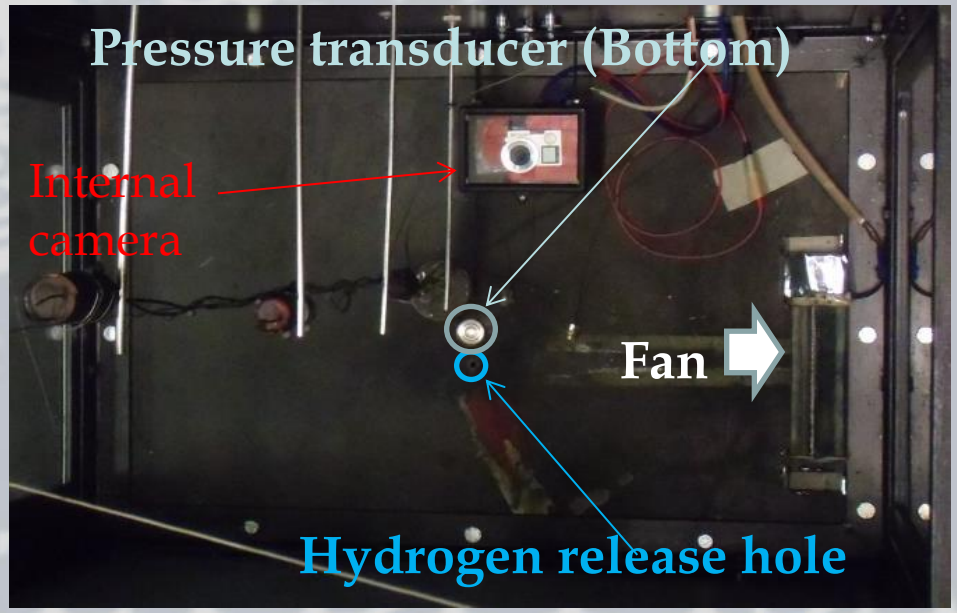
Pressure transducers:

Bottom: Center of the floor

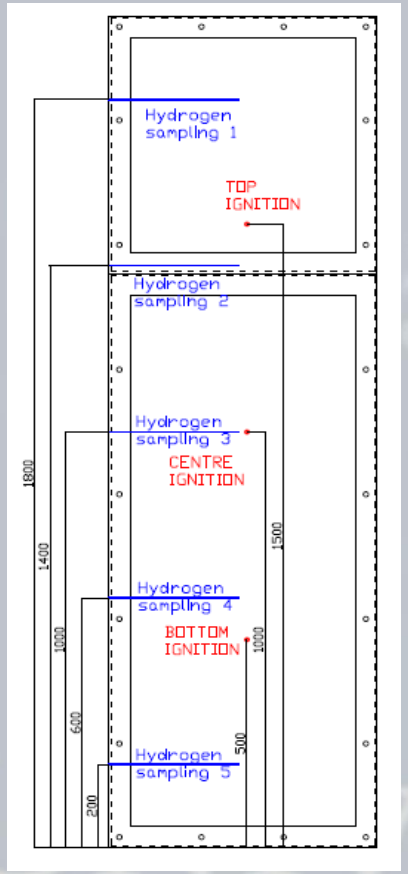
Side: On the centerline of the back plate 1.5 m above the floor

External camera





Experimental set-up



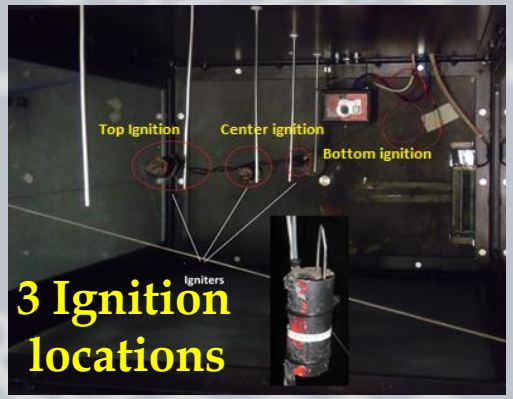
5 Sampling locations

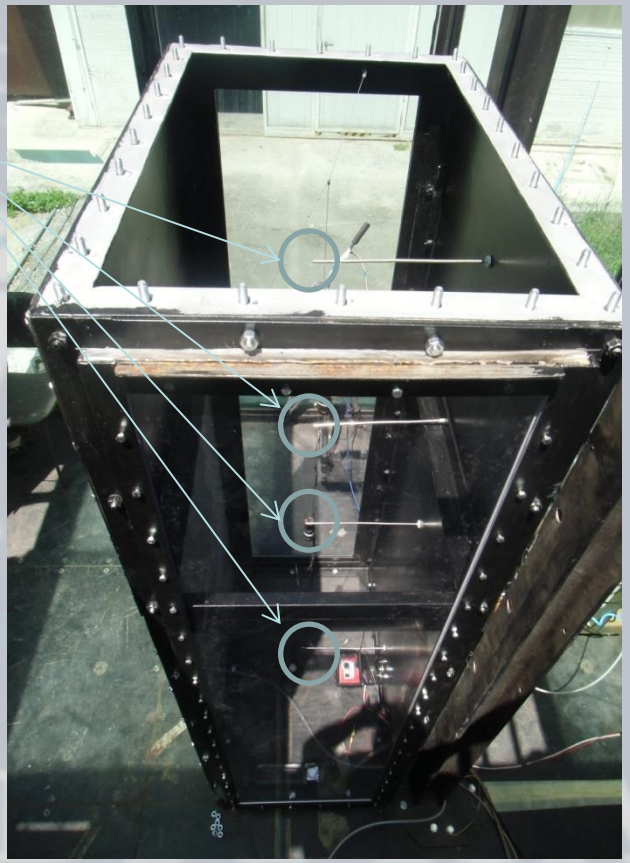
Ignition location:

Bottom:
On the centerline 0.5m above the floor

Centre:
On the centerline 1m above the floor

Top:
On the centerline 1.5 m above the floor





Experimental set-up

Internal obstacle configuration

Empty SSE | 1 bottle | 3 bottles

Free volume~1.141 m^3

Free volume~1.085 m^3

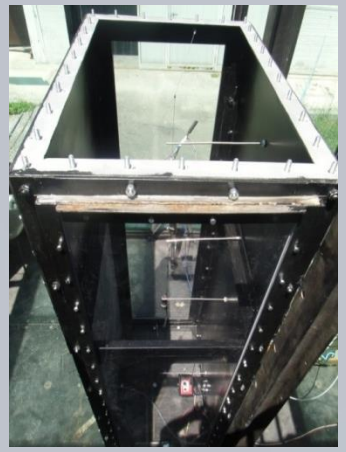
Volume reduction 4.86%

Free volume~0.974 m^3

Volume reduction 14.58%

Experimental set-up

Top vent



Front vent

Vent type

Plastic sheets

1

2

3

FIKE vents

1

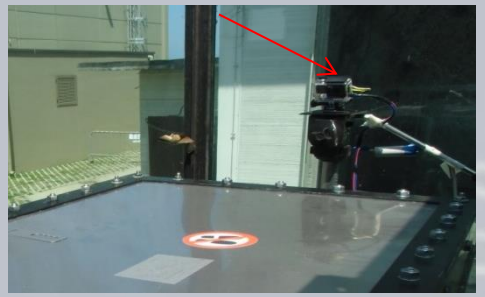
2

3

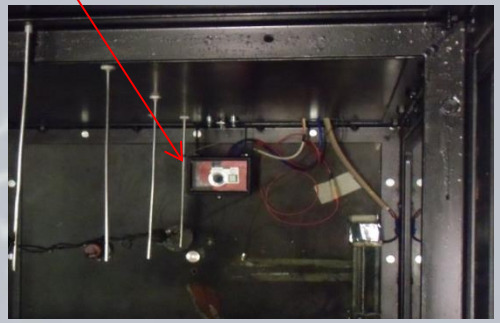
Vent locations

Experimental set-up

External camera



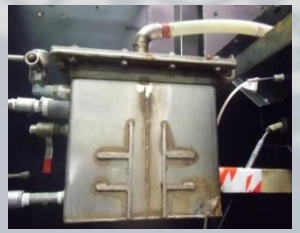
Internal camera



Video recording

Video recording was performed at **240 fps** (frames per second)

Salt water spray injection system

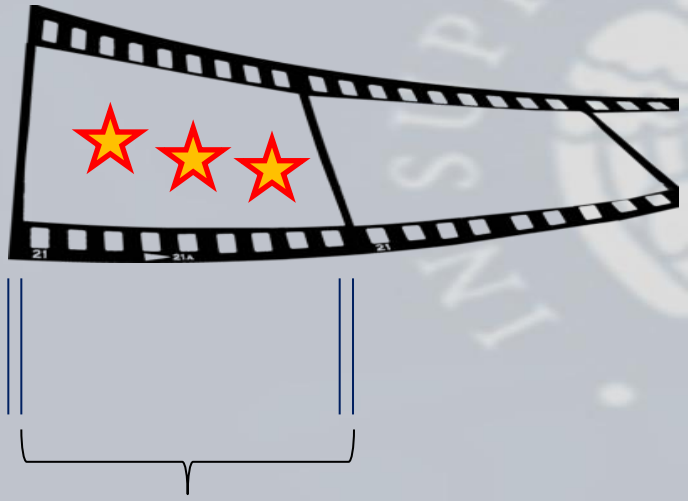


Spray injection location

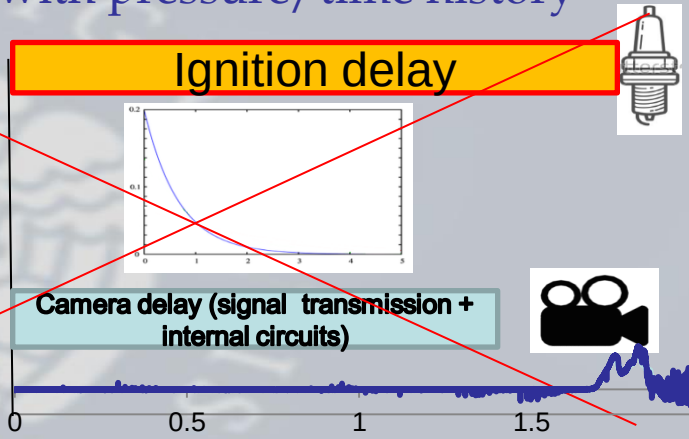
Visible Emission Spectra Sodium Chloride

Experimental set-up

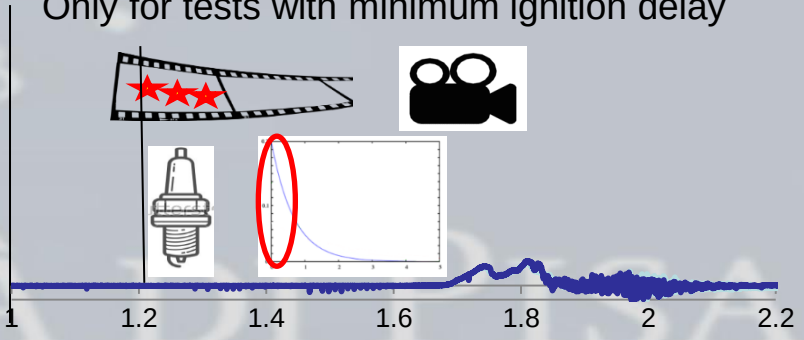
Video recording : Synchronization with pressure/time history



$Tr+Ts = 1/240\ s = 4.17\ 10^{-3}\ s$

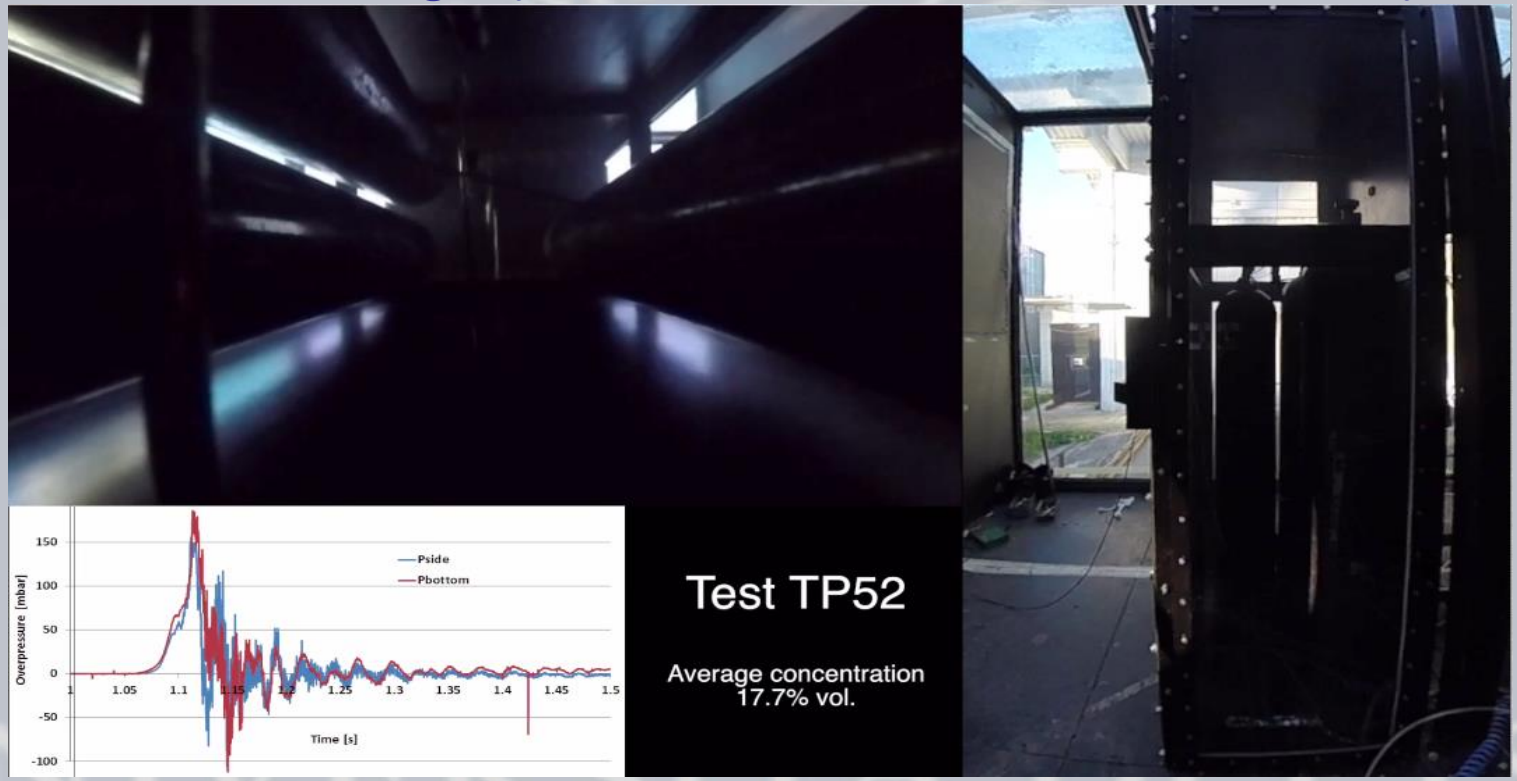


Only for tests with minimum ignition delay



Experimental set-up

Video recording : Synchronization with pressure/time history



Video has been slowed down 10 times

Pivotal moments in vented deflagrations

Every vented deflagration involve two crucial moments:

- **Vent opening**
- **Flame reaches the vent**

Both of these pivotal moment modify the boundary condition in which the flame front is developing and trigger perturbations.

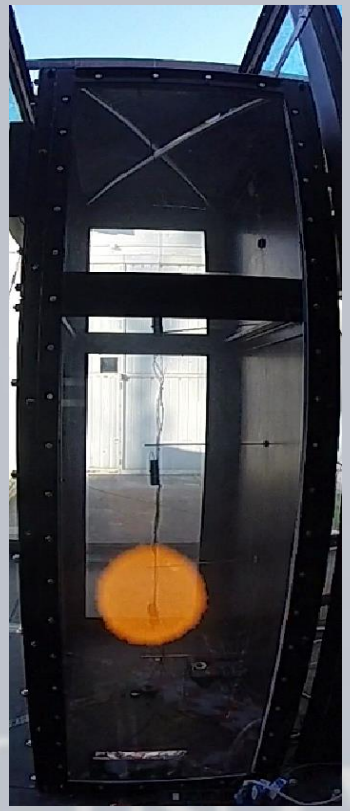
Vent opening:

- Introduces perturbations generated by the dP at the vent surface which in turn originate a flow field directed towards the vent area
- Changes the distribution of the forces applied to the flame front by the expansion of the combustion products inside the «flame bubble»

Flame front reaches the vent area:

- Introduces perturbations generated by the sudden increase of the dV/dt at the vent surface which in turn originates perturbations
- The generated combustion products are removed towards the vent area and do not contribute anymore to the acceleration of the flame front (flame tends to become "quasi-stationary")

Vent opening:

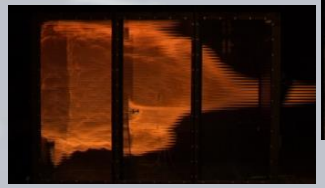


Frame 584 (TP73)

Frame 587 (TP73)

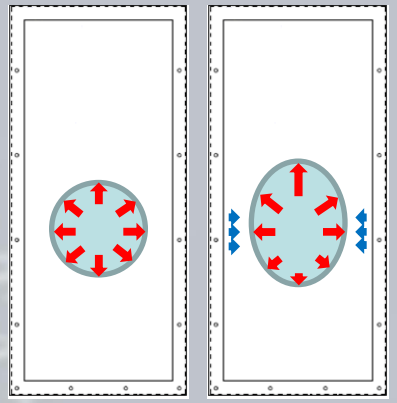
Frame 590 (TP73)

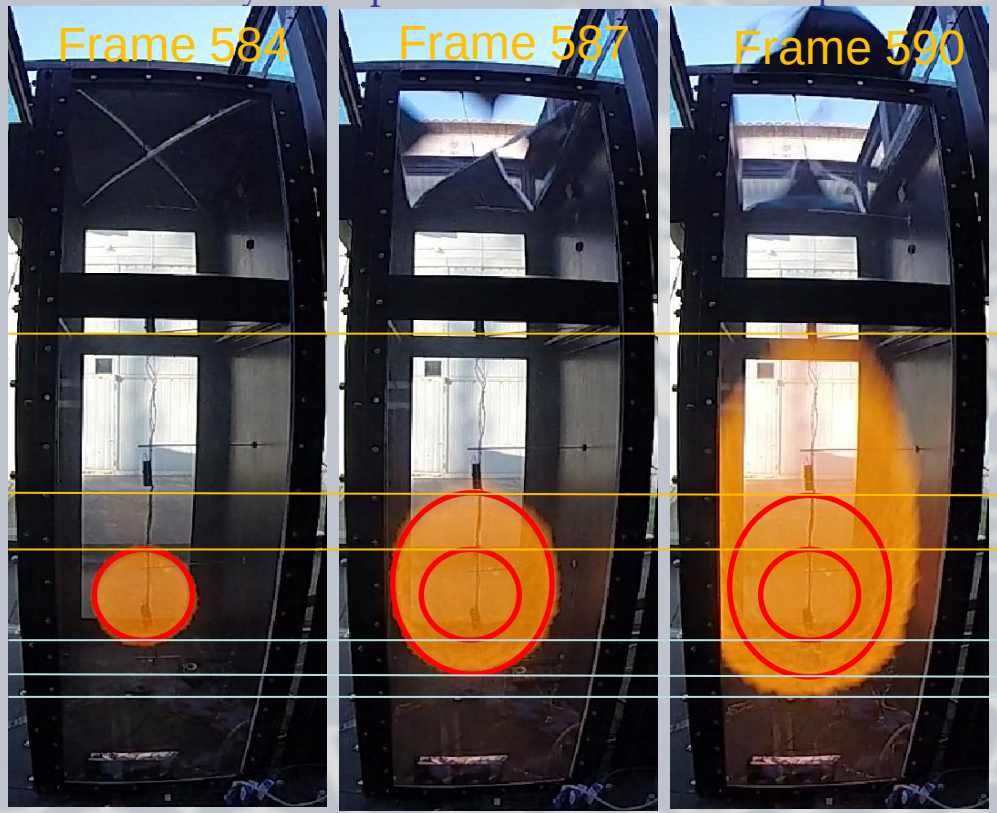
1. Introduces perturbations (accelerations) generated by the dP at the vent (The flame front is accelerated outwards by the expansion of the combustion products, so the effect of the superimposed "acoustic" accelerations is negligible)
2. Originate a flow field directed towards the vent area



3. Changes the distribution of the forces applied to the flame front by the expansion of the combustion products inside the «flame bubble»

Vent opening: Provokes changes the distribution of the forces applied to the flame front by the expansion of the combustion products





Velocity of the flame front increasing

Flame front travels 0.5 to 0.6 m
in 1 frame 12.5 10^{-3} s
~40 m/s

Velocity of the flame front decreasing

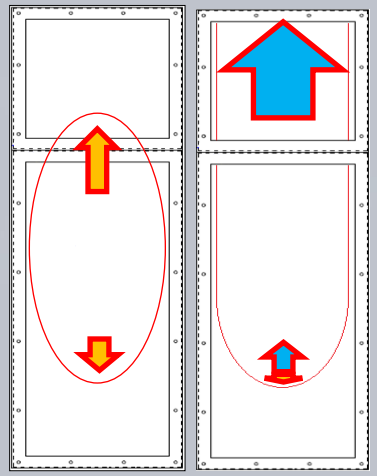
Test TP73 (18%vol)

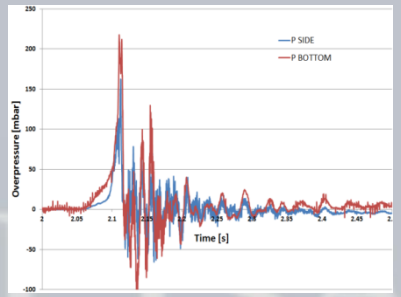
Flame front reaching the vent area:

Frame 594 (TP73)

Frame 595 (TP73)

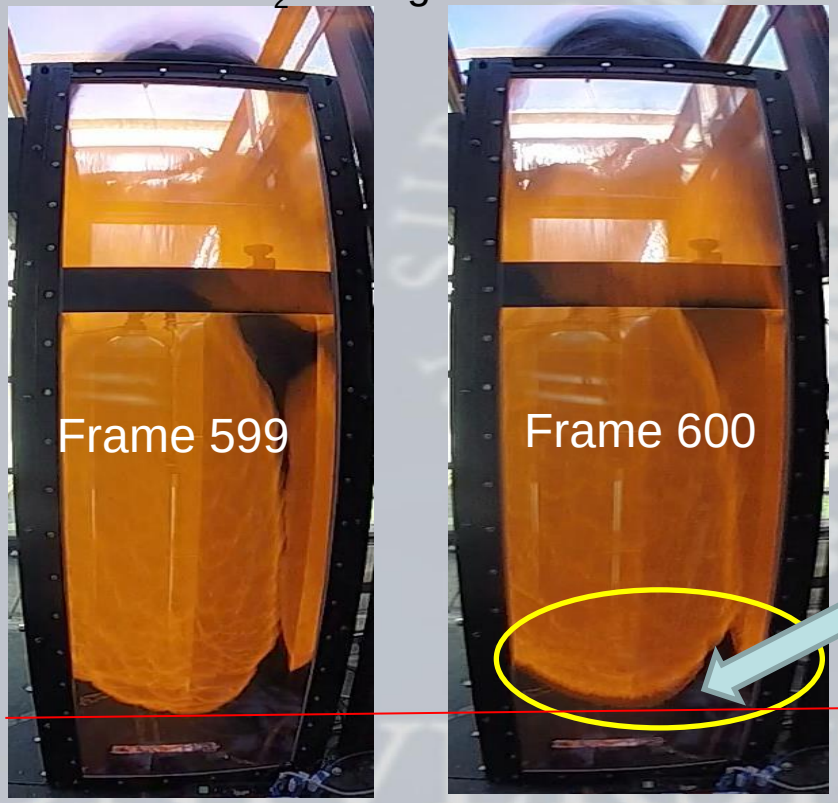
1. Introduces perturbations (accelerations) generated by the sudden change of dV/dt at the vent (Such perturbation travel at the speed of sound)
    1. Helmholtz oscillations
    2. Acoustic response of the chamber
2. Combustion products generated inside the «flame bubble» direct mostly towards the vent area and do not contribute anymore to the acceleration of the flame front in outward direction (Flame front behaves like a free standing flame)





Flame front reaching the vent area: accelerations

Test TP55: H_2 average conc. 17.8%



The abrupt increase of the flow out of the vent area is responsible for the discontinuity that generates the acoustic response of the chamber:

1. Helmholtz oscillations
2. Acoustic response of the chamber

$$\frac{dV}{dt} = C_d \cdot A_v \cdot (2\Delta P/\rho)^{\frac{1}{2}}$$

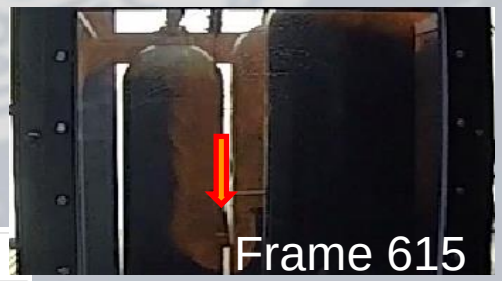
Distance traveled by perturbation (acceleration) 1.8 m

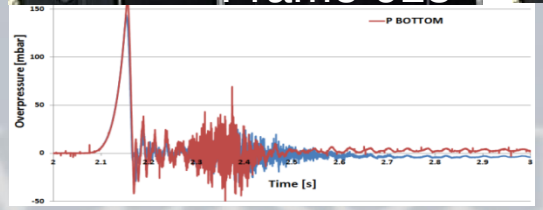
Time ≤ 1 frame = 1/240s = 4.17 10^{-3}s

$$v_p \geq \frac{1.8m}{\frac{1}{240}s} \geq 432\ \frac{m}{s}$$

Compatible with a perturbation travelling with the speed of sound in the combustion products

Flame front reaching the vent area: flow field affecting the flame front opposite the vent

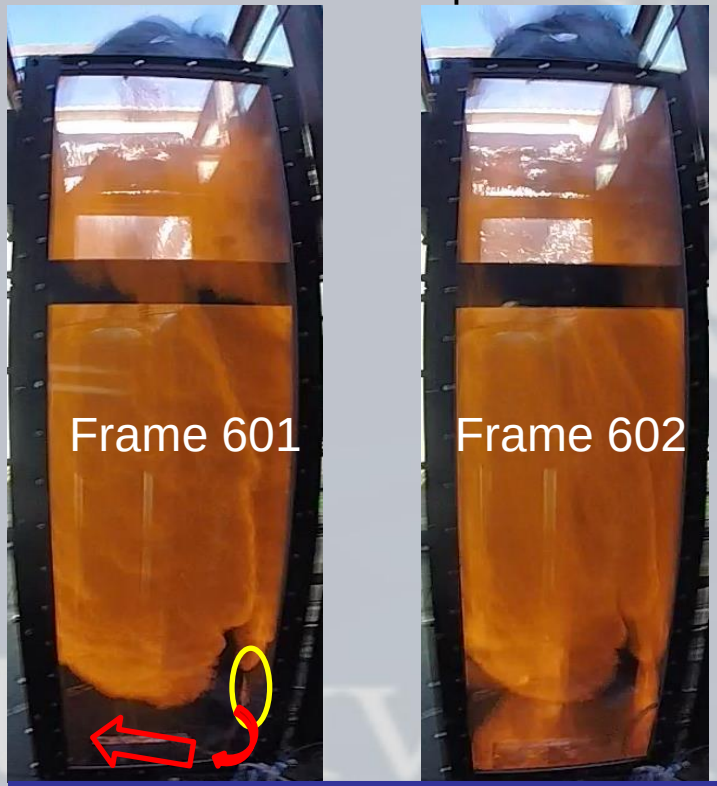




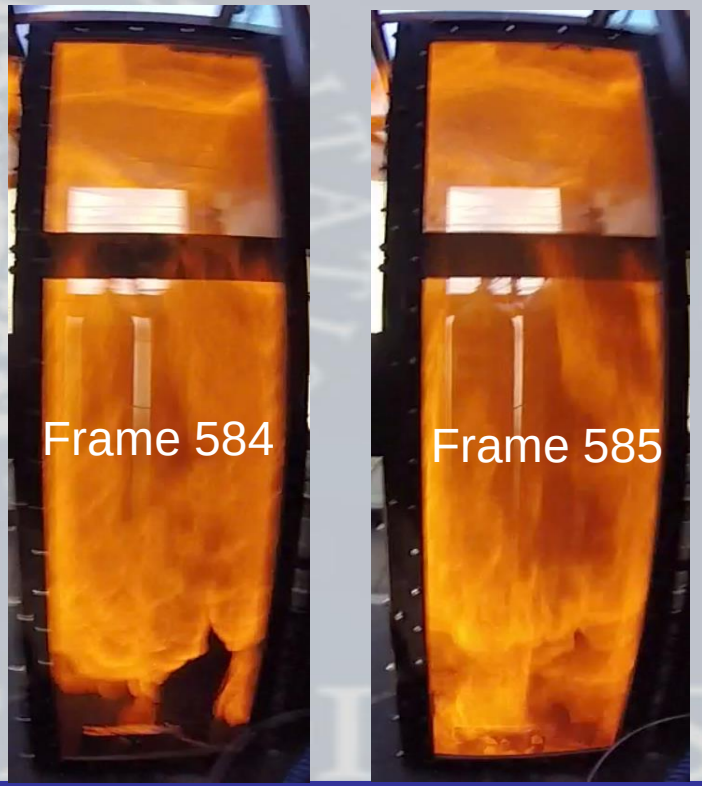
Combustion products generated inside the «flame bubble» are sucked towards the vent area, the generated flow field drags the flame front towards the vent, the flame "survives" only in regions were the velocities are lower.

Local pressure peaks: flow field around obstacles

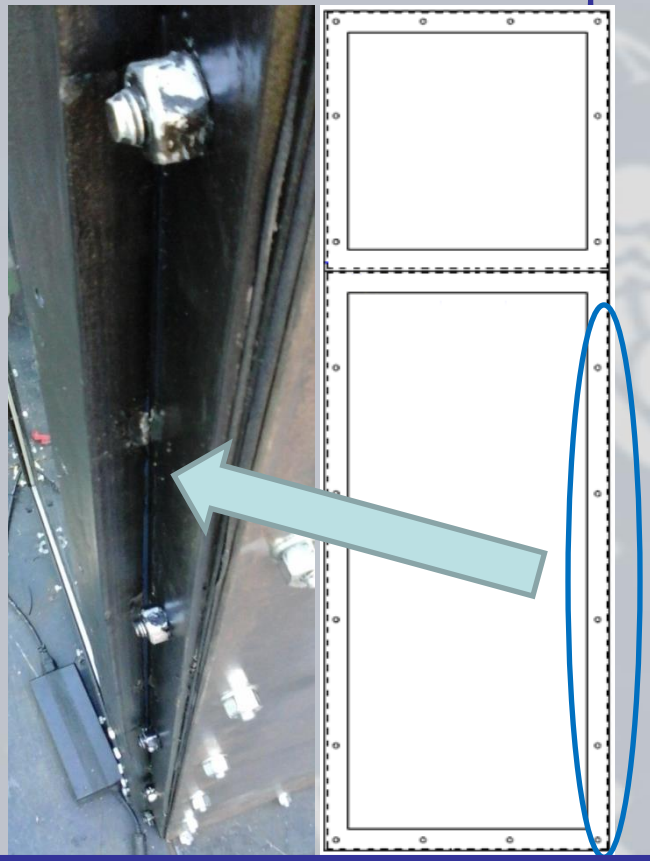
Test TP55: H_2 average conc. 17.8%
3 bottles – Top vent

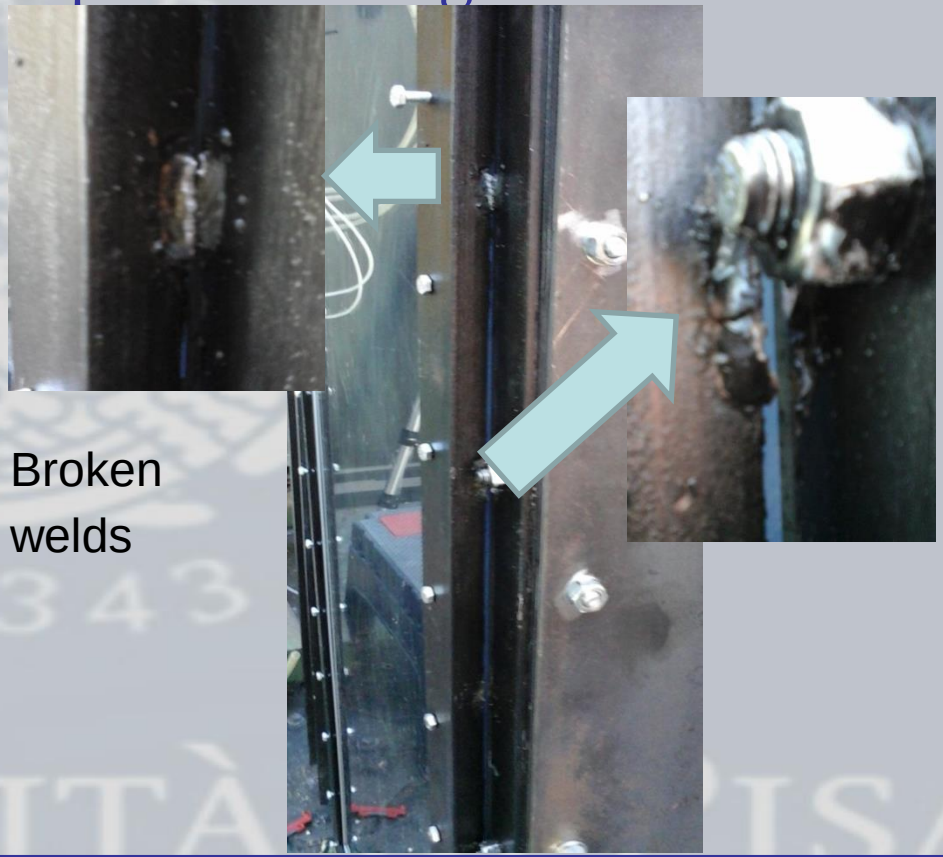


Test TP52: H_2 average conc. 17.7%
3 bottles – Front vent



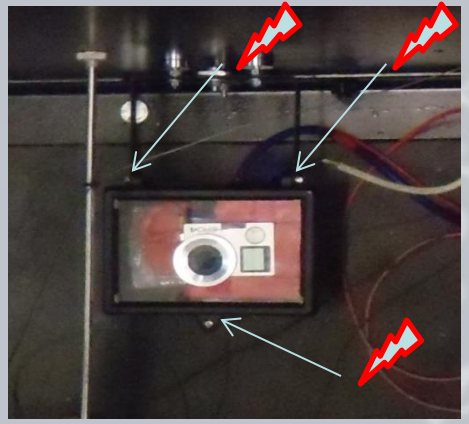
Local pressure peaks: damages





Broken welds

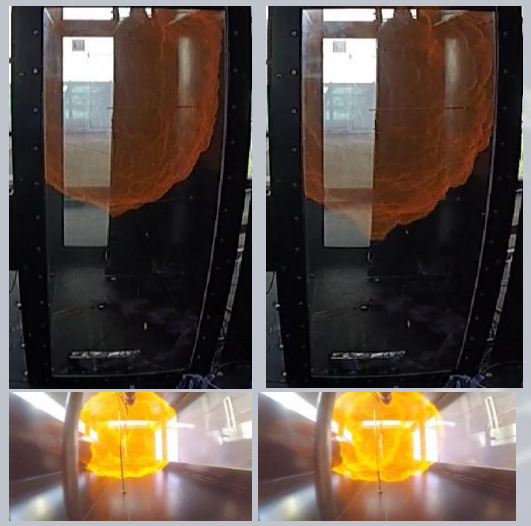
Local pressure peaks: damages



Camera protection case cap removed
(broken hinges and closure – aluminum)

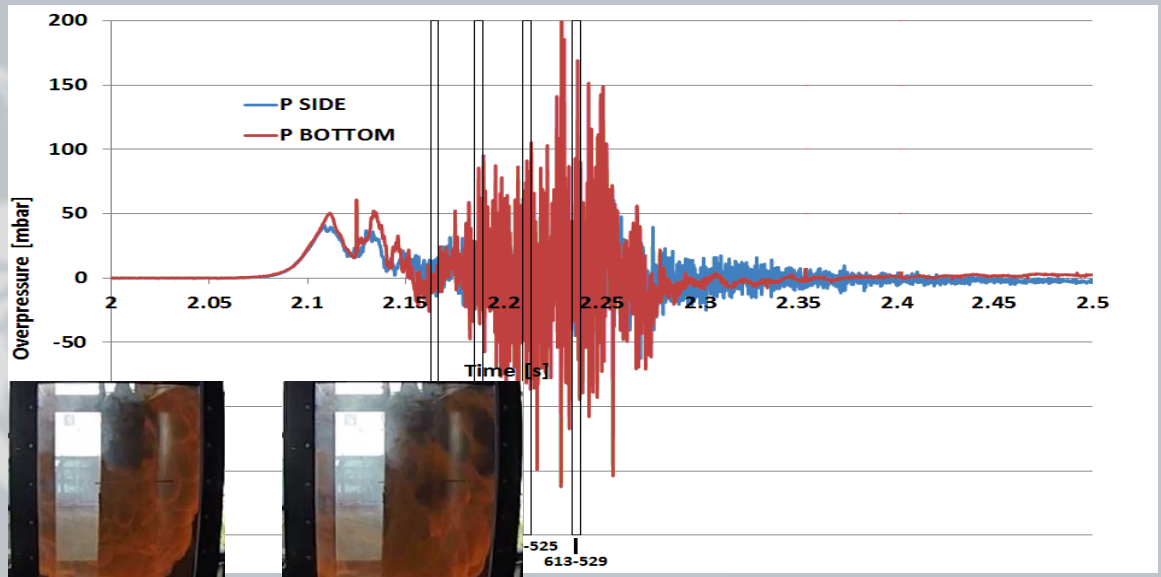
Displaced camera

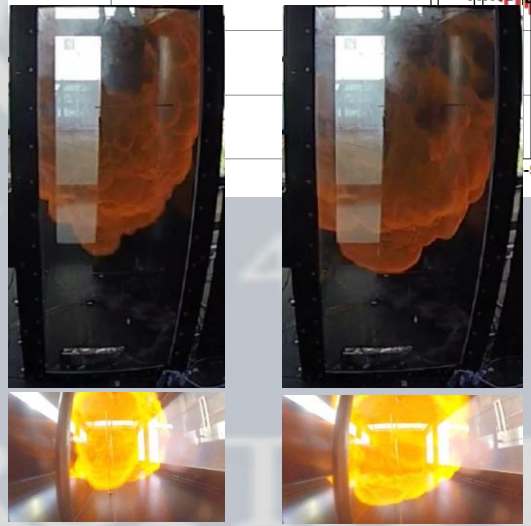
Acoustic oscillations



Frames
601
517

Frames
605
521





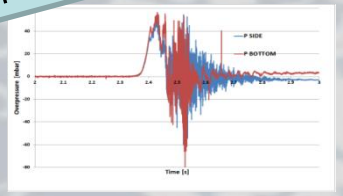
Frames
609
525

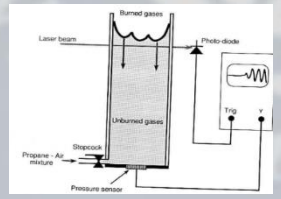
Frames
613
529

Flame front reaching the vent area:(free standing flame behavior after venting)

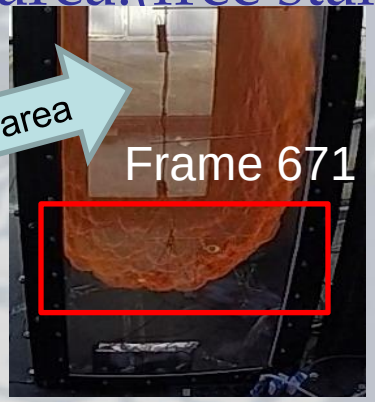
Test TP74
(14.3%vol.)

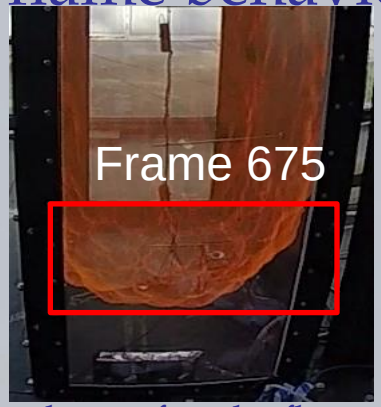
Flame front before reaching the vent area



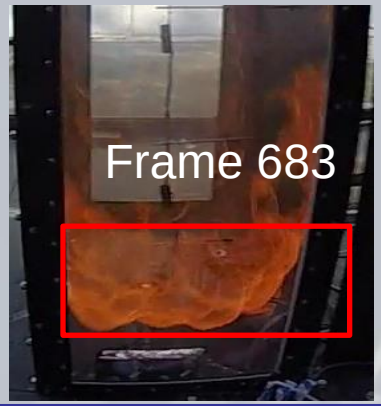


Geometrical analogy with the experimental set-up of Searby (Acoustic instabilities in premixed flames -Comb. Science and Tech. 1992 Vol.81)

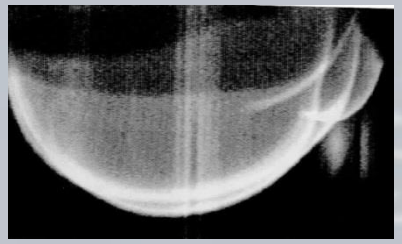




Progressive changes in the flame shape after the flame front reaches the vent area



Flame front reaching the vent area:(flame shape during last phase of deflagration)



Luminous emission from spontaneously curved flames in the absence of acoustic instabilities

"The flame typically has a curved shape with large "soft" cells generated by Darreius-Landau instabilities"

G. Searby (Acoustic instabilities in premixed flames -Comb. Science and Tech. 1992 Vol.81)

HySEA CONSORTIUM

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IMPETUS
driving precision

Fike

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1945

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THANK YOU
For your attention