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Deflagration propagation through fire extinguishing foam

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Pro-Science



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Introduction

Objectives

- The aim of the experiment is to demonstrate the interaction of fire extinguishing foam with H_2 , to answer the questions: Can the H_2 enriched foam become burnable and what is the behavior of flame propagation?
- A rectangular reservoir $H \times W \times L = 0.3 \times 1 \times 2$ m open on the top is used as combustion channel. The channel is filled with H_2 enriched foam and ignited using a pilot flame.

Type of foam	Foam A	Foam B
15 % vol H_2	X	X
18 % vol H_2	X	
20 % vol H_2	X	X
25 % vol H_2	X	X
30 % vol H_2	X	X
20 % vol H_2 Channel with obstacles	X	

Foam A:

Commercial „Family bubble bath“ foam

Foam B:

Professional firefighter extinguisher foam

Additionally the combustion behavior of the H_2 -enriched foams have been studied in detail in open-end transparent channels. (not in frames of HyTunnel-CS)

Foam specifications

Foam A) Commercial family „bubble bath“ foam

Modell foam simple to handel: no “Safety Data Sheet” !



Foam B) Professional firefighter extinguisher foam

Dr.Sthamer, Hamburg

STHAMEX-class A Classic 1% F-15 #9144

<https://www.sthamer.com/de/pdf/Produktdatenblatt/PD - 9144 - V07 - STHAMEX-class A Classic 1 F-15 9144 - DE.pdf>

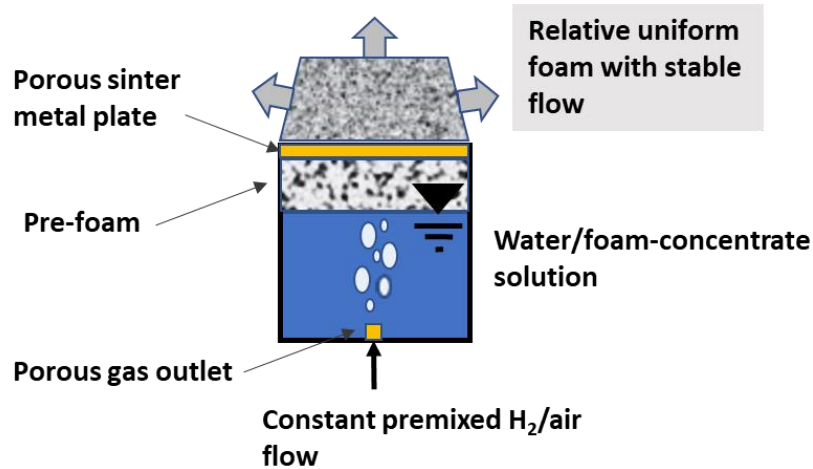
Safety Data Sheet according to Regulation (EC) No. 1907/2006 (REACH) STHAMEX® -class A Classic 1% F-15 #9144
(https://www.sthamer.com/en/customer/download_data_sheets.php)



Foam specifications: foam formation

A foam is commonly defined as a dispersion of gas bubbles in a liquid.

Foam formation with premixed H_2 /air!



The foam properties is manly influenced by the hardware of the foam generator.

(dimensions and porosity of the gas outlet and sinter plate)

Other parameters: Foam concentrate solution; gas flow rate; level of the foam solution.

Foam aging: Drainage of liquid with time, stability of the foam bubbles.

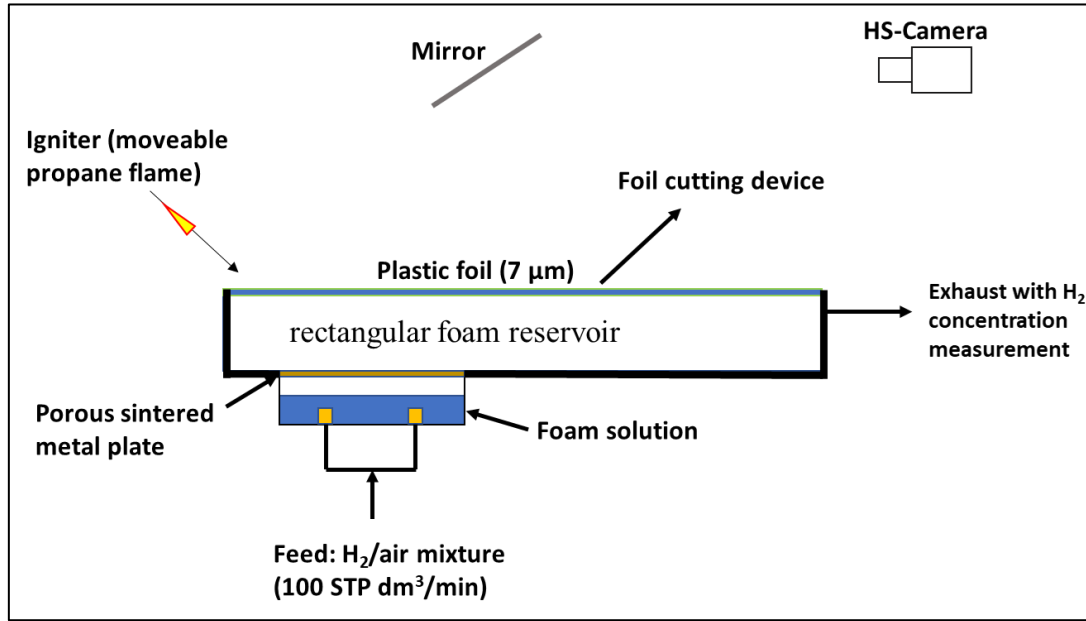


TRAVIS AIR FORCE BASE, CA, UNITED STATES
09.11.2020. <https://www.dvidshub.net/image/6370730/new-high-expansion-foam-system-protects-air-force-assets>

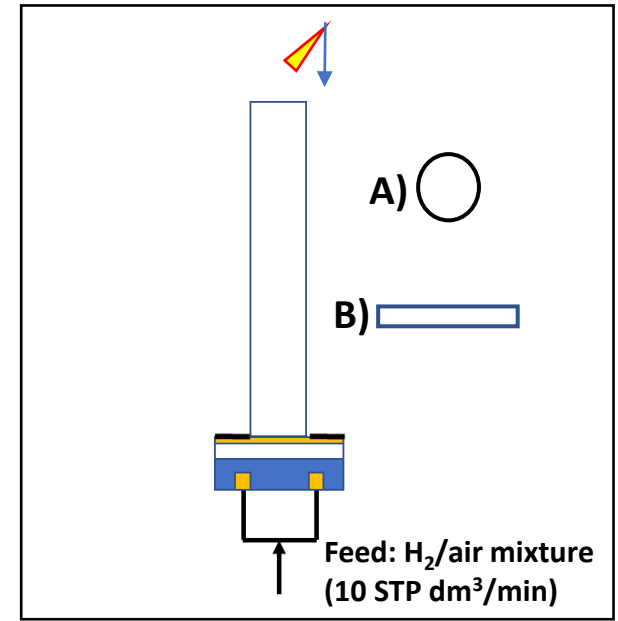


https://www.sthamer.com/de/pdf/prospekte/Prospekt_2017_en.pdf

Test facilities



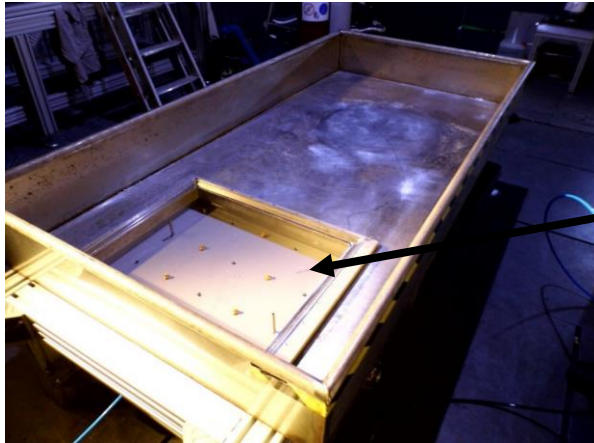
Horizontal rectangular foam reservoir (2 m x 1 m x 0.3 m) open from top (pool).



Vertical open end tube with two different cross sections.

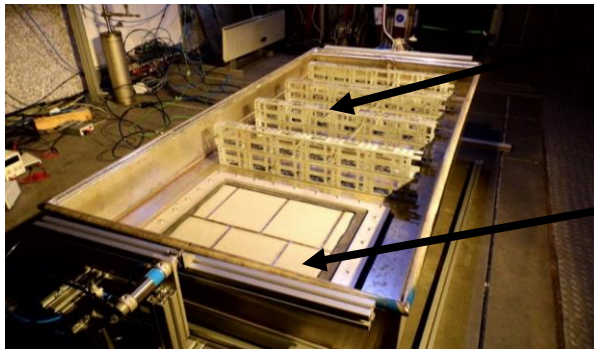
- A) Cylindrical (d = 0.09 m; l = 1.4 m)
- B) Rectangular (0.2 x 0.02 m; l = 2 m)

Experimental setup



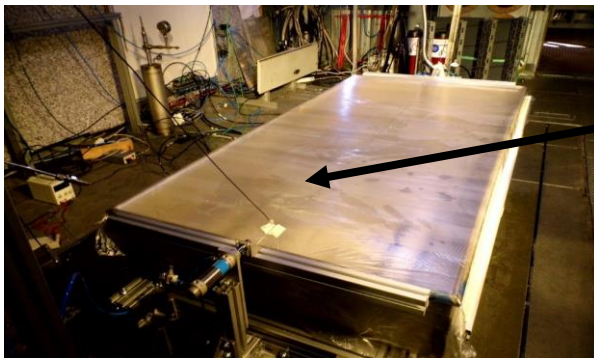
Horizontal rectangular
foam reservoir

Open foam
generator

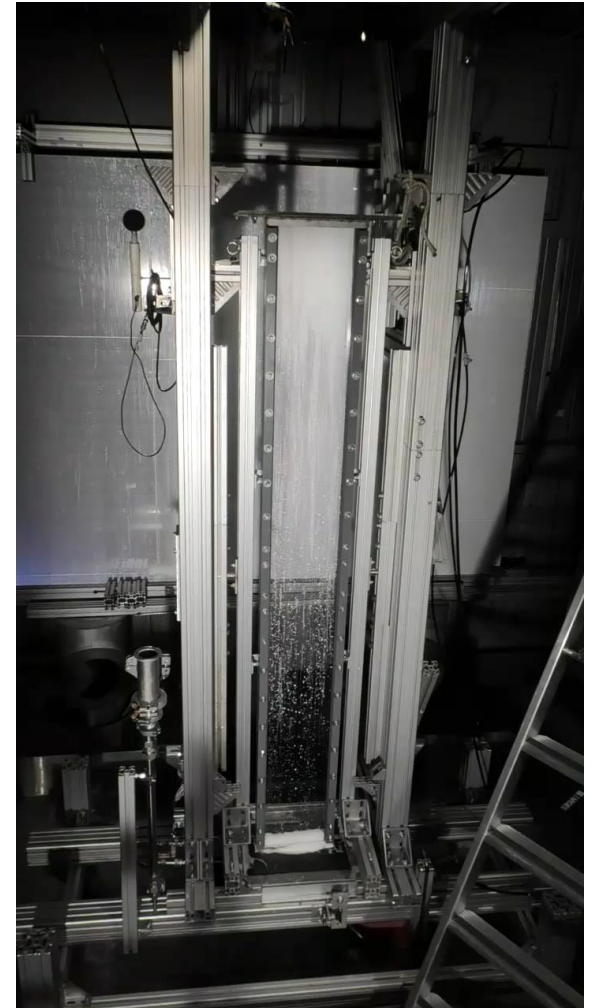


Obstacles, blockage
ratio 50 %

Foam generator
with sinter plate



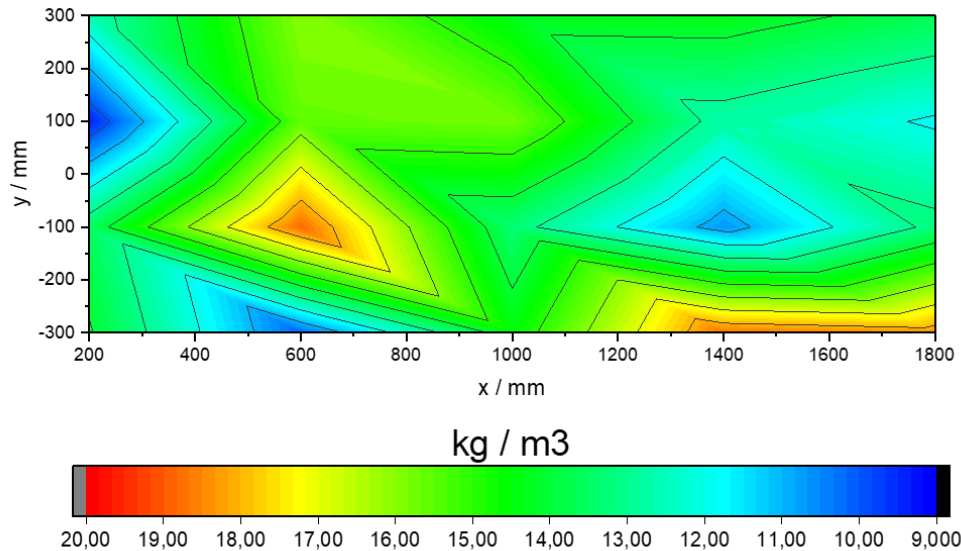
Covered with
thin foil ($\sim 7 \mu\text{m}$)



Vertical open end tube 2 m:
cross sections (0.2 x 0.02 m)

Foam density

Horizontal rectangular reservoir
firefighter extinguisher foam B (0.5 % concentrate)

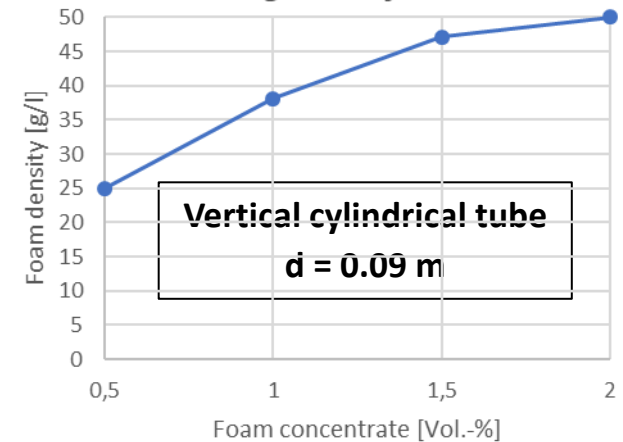


Horizontal rectangular reservoir: Filling time 5 min.
Vertical cylindrical tubes: Filling time 1 min.

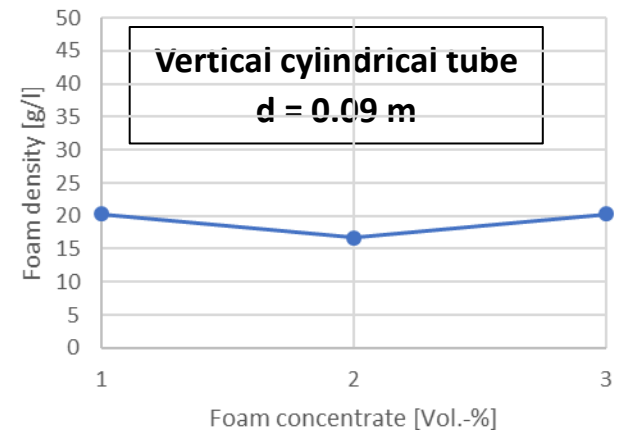
Foam aging: Drainage of liquid with time.

All experiments are performed with medium expansion foam: foam expansion ratio is between 20 to 200.

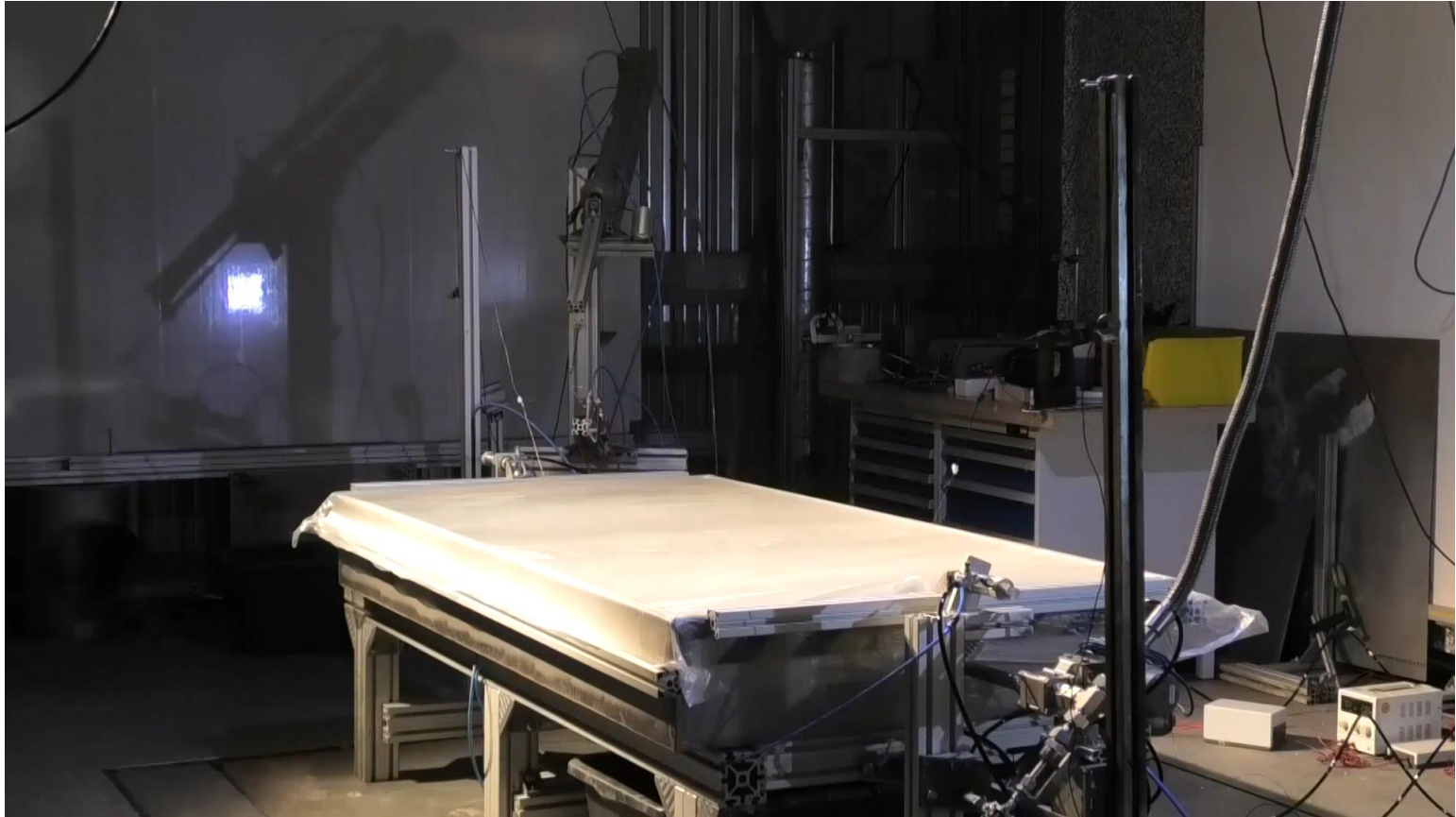
*Firefighter
extinguisher foam B*



Family „bubble bath“ foam A

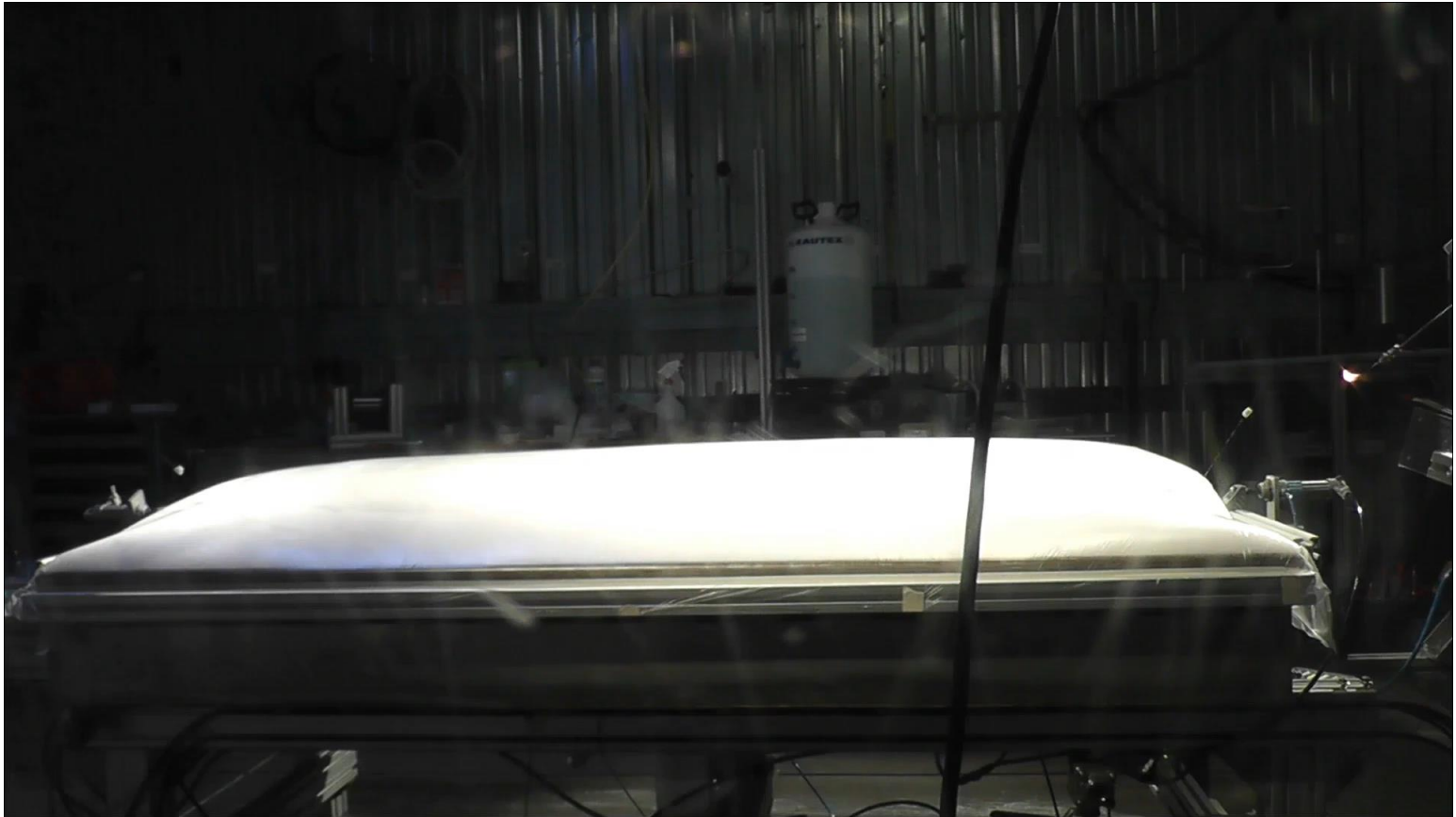


Experimental setup



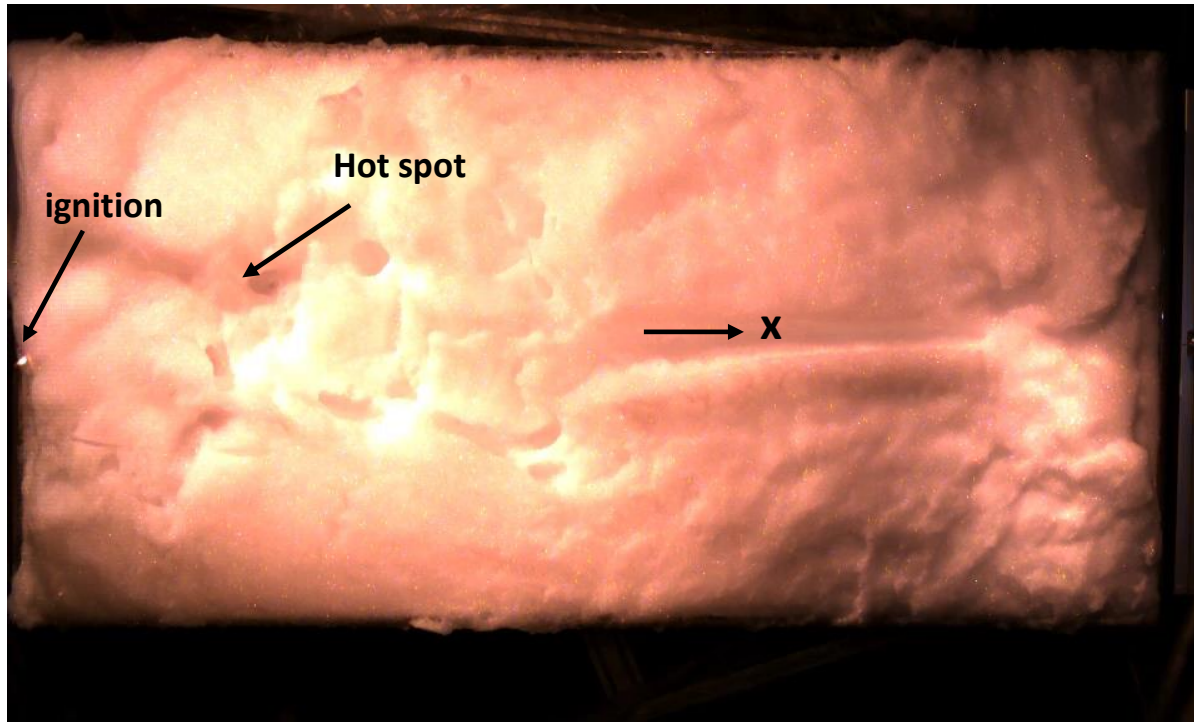
20% H₂ in air Model foam A

Experimental setup

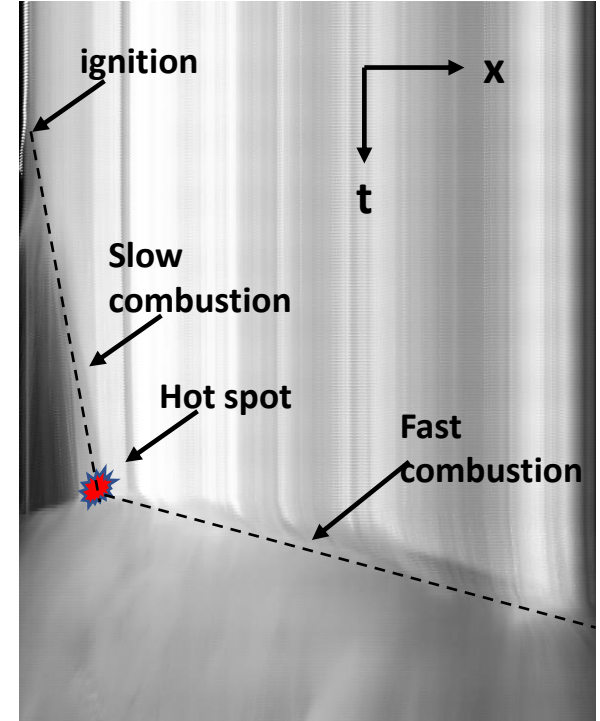


25% H₂ in air *firefighter extinguisher foam* (Foam B)

Results



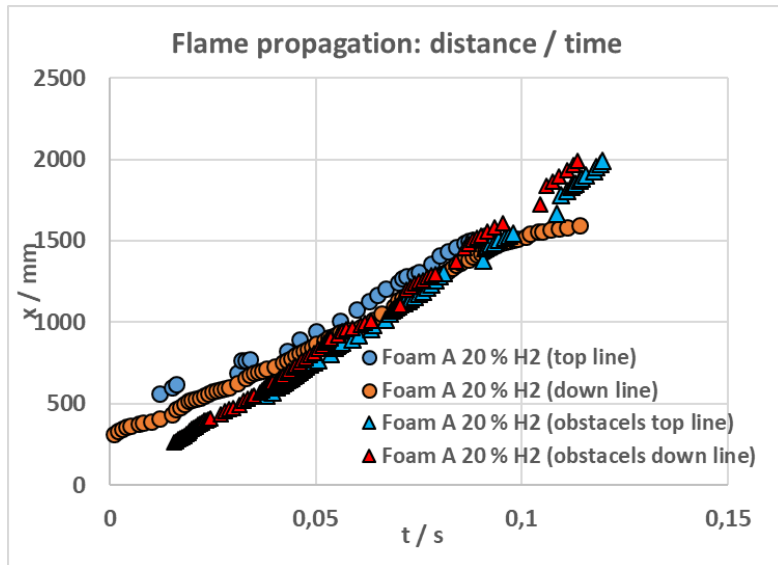
25% H₂ in air firefighter extinguisher foam (Foam B); 1000 f/s



Stack montage: center line

After ignition the foam burns slowly. A hot spot changes the burning velocity rapidly.

Results: influence of obstacles



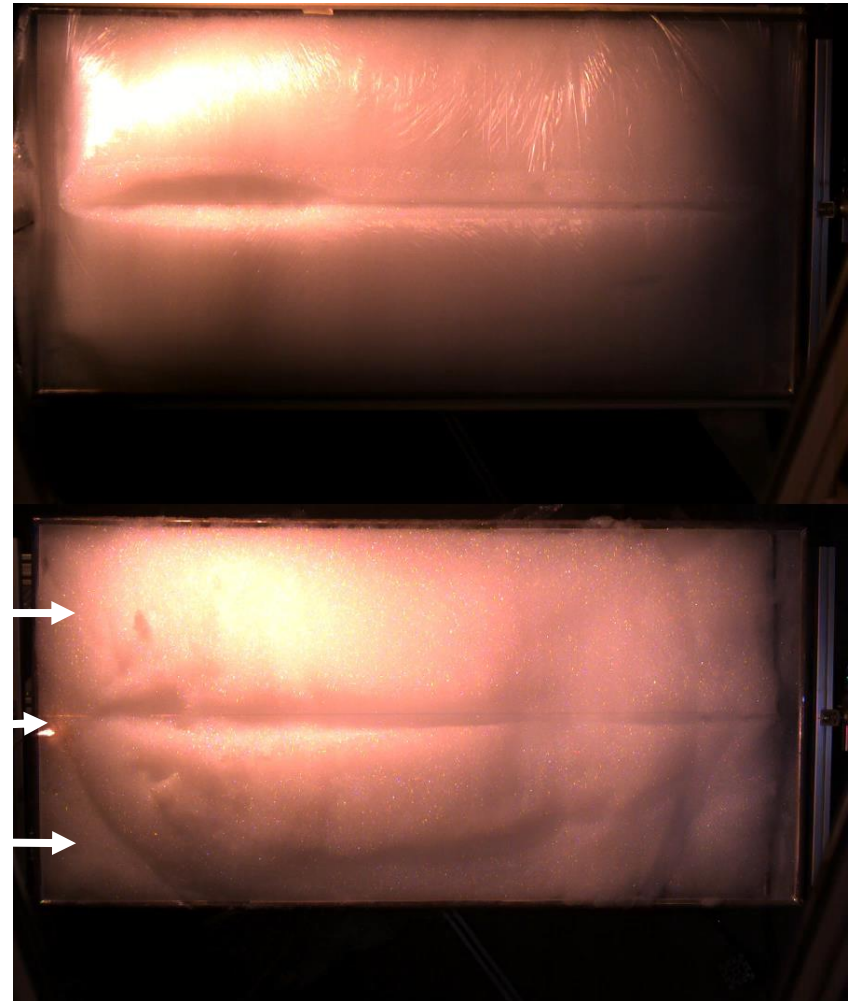
Flame velocity ~ 18 to 20 m/s

Burning velocity is not sensitive to obstacles.

Top line

Centre line

Down line



20% H₂ in air Model foam A (1000 f/s)

Top: with obstacles (BR ~ 50 %)

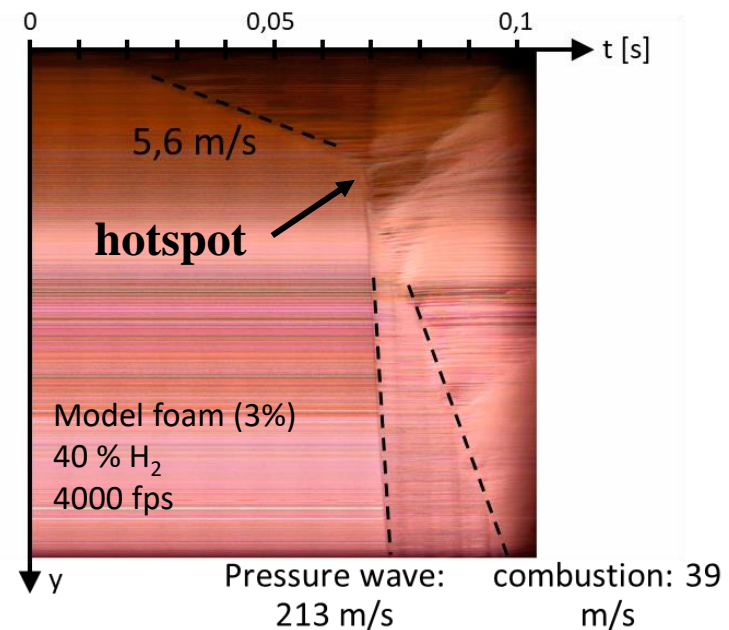
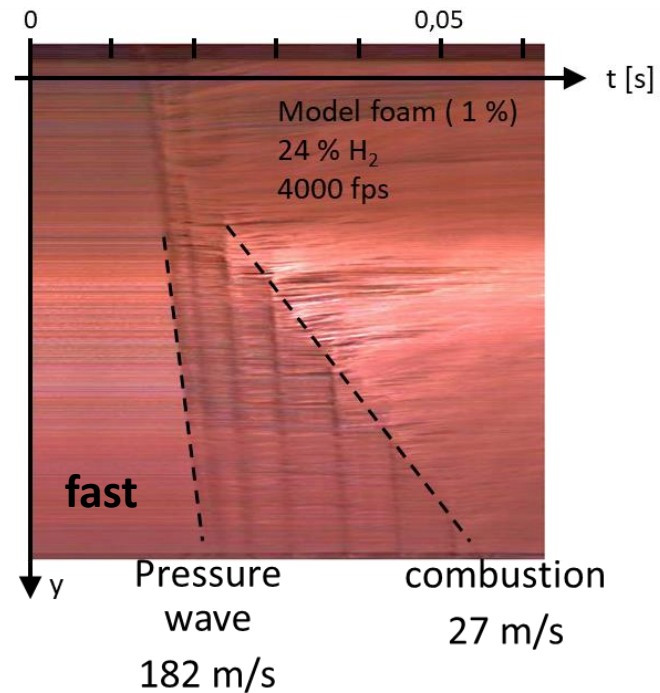
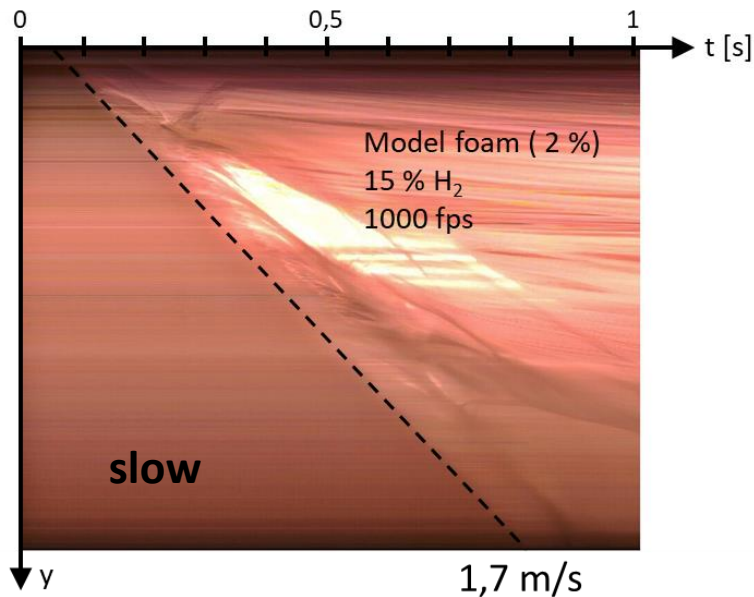
Down: no obstacles

Results

Vertical open end tube $d = 90$ mm:

Three combustion regimes are observed.

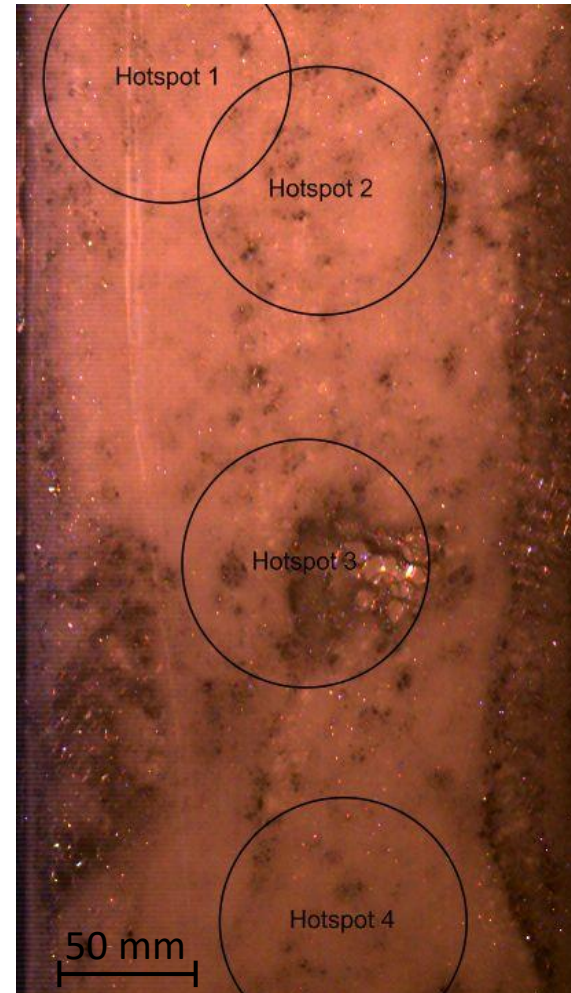
- slow combustion
- fast combustion
- slow \rightarrow hotspot \rightarrow fast



Results: Example Hotspots

Rectangular channel (0.2 x 0.02 m; $l = 2$ m)

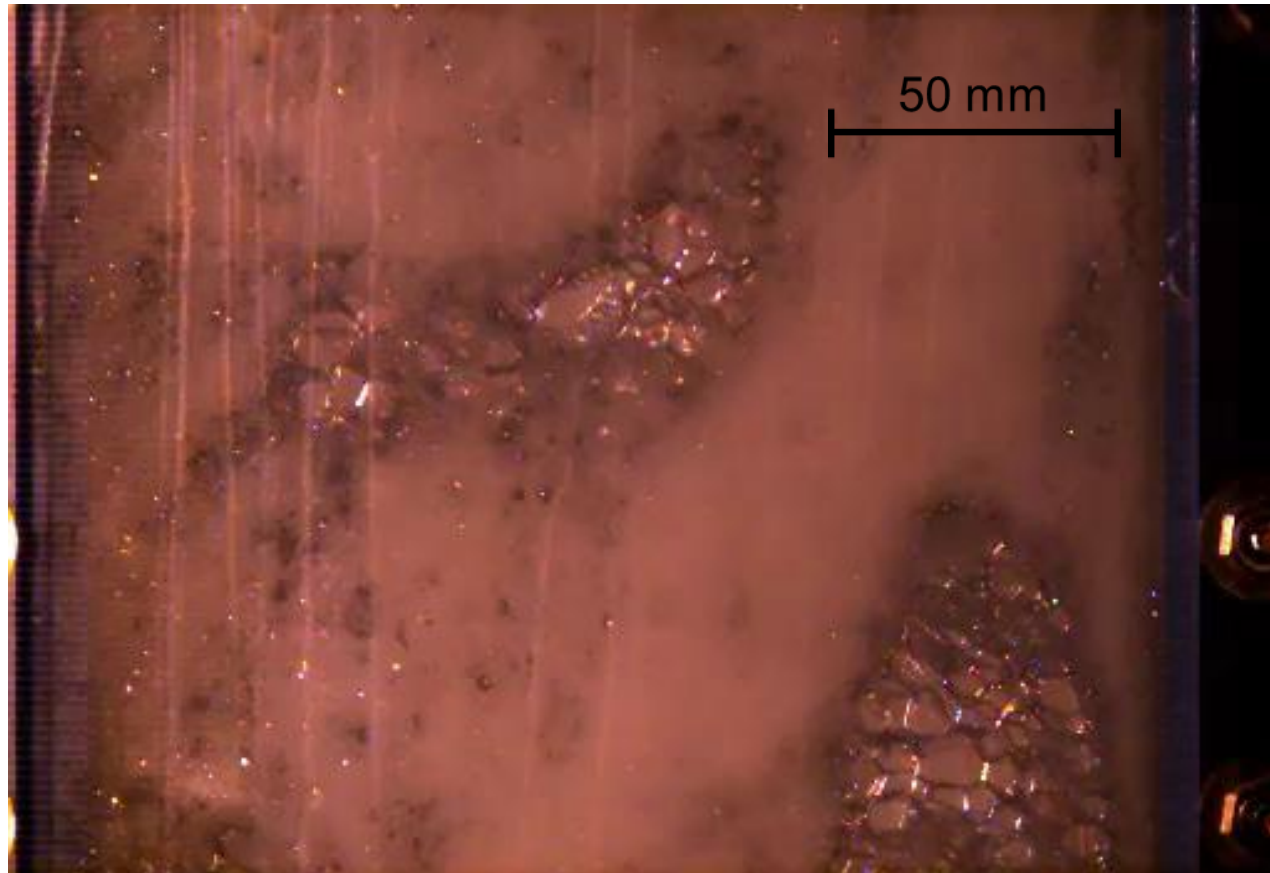
Example Hotspots: Model foam (2 %); 20 % H₂; 16000 f/s.



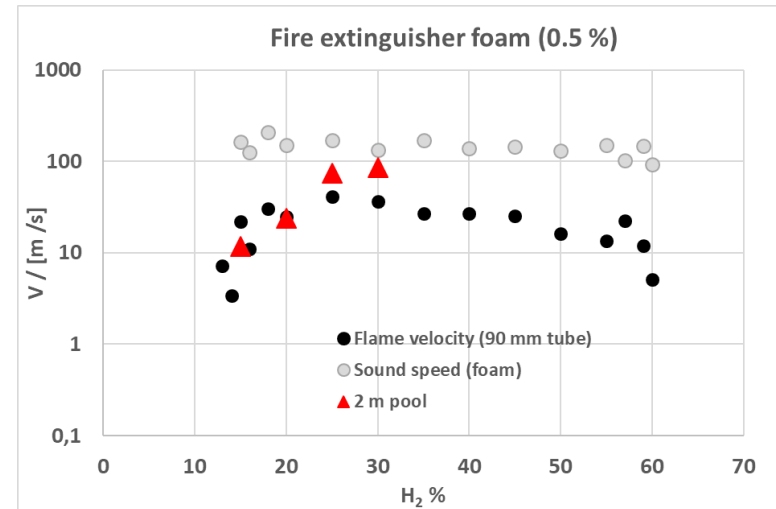
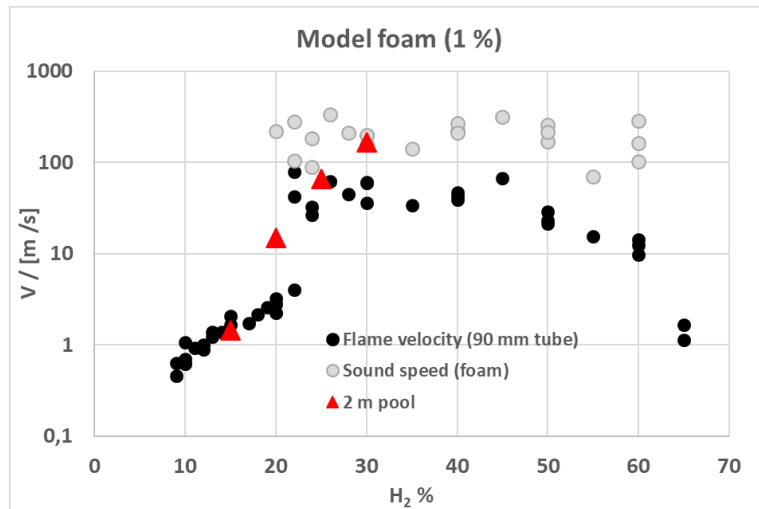
Results: Example Hotspots

Rectangular channel (0.2 x 0.02 m; $l = 2$ m) Model foam (2 %); 22 % H₂; 3000 f/s.

Foam oscillated before the flame.



Results: combustion velocity

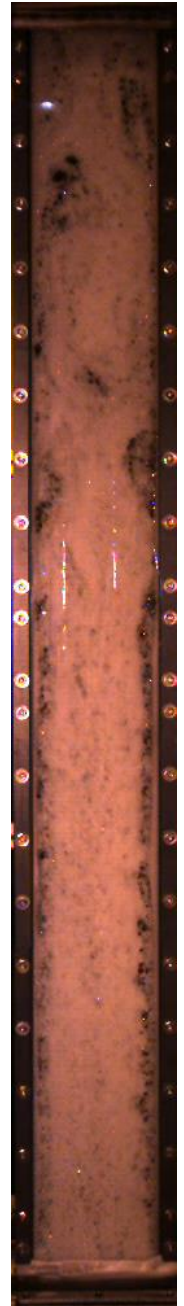
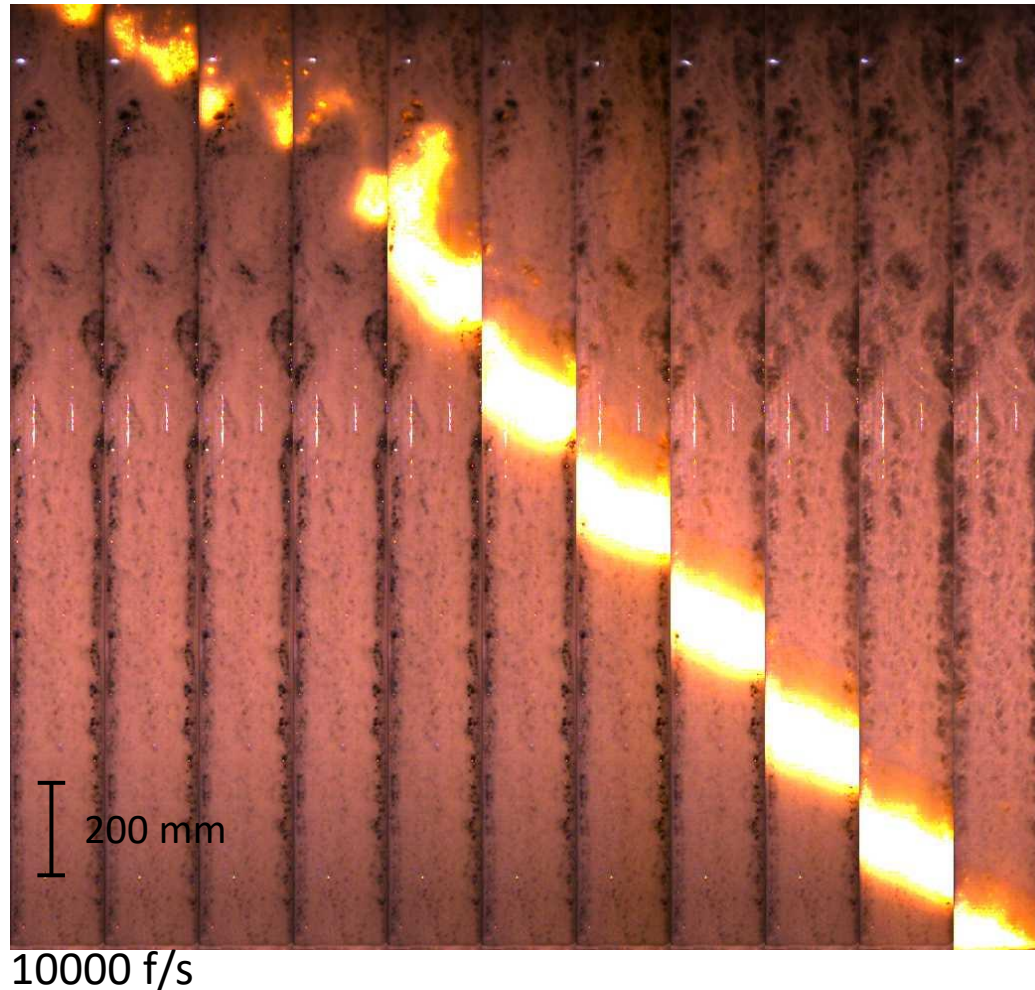


- Range of flammability for downward propagation (9 % H_2 to 65 % H_2).
- Minor difference between model foam (1 %) and fire extinguisher foam (0.5).
- Observed flame propagation velocity lies below sound speed in the foam.

Detonation in foam

Model foam (2 %) H_2/O_2 -mixture (50:50)

Detonation velocity = 1180 m/s (Pure gas: CJ = 2324,5 m/s)



Summary

Burnable or exploding fire extinguisher foam is a curio itself.

- Foam built with H_2 /air mixture becomes burnable.
- The flammability limit in foam is comparable with that in pure gas (H_2 /air).
- H_2 can be fixed in foam, no rapid dilution.
- A special abrupt flame acceleration was observed.

Acknowledgements

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