Aalto University

Increased Fire-Induced Pressure in Airtight Buildings
– New Risks for Evacuation & Smoke Management

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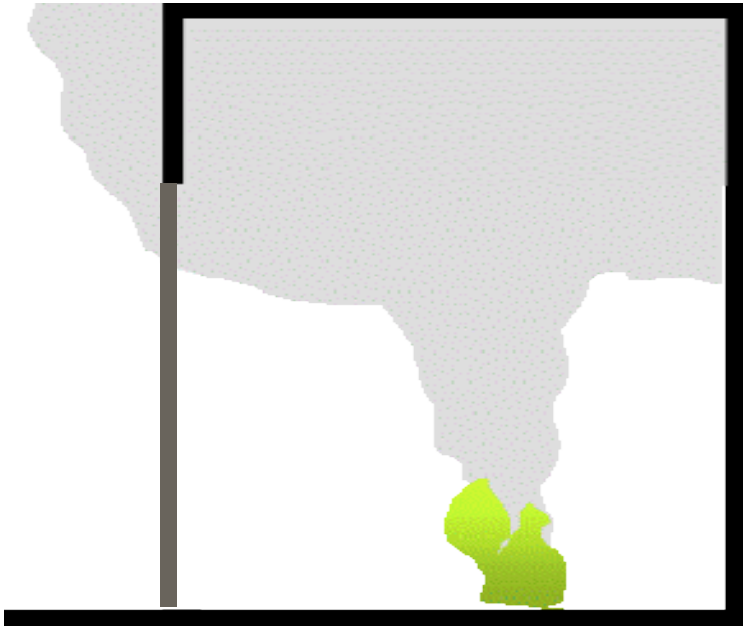
Sustainable fire engineering -conference, Dublin, September 30, 2016

Background

$$pV = nRT$$



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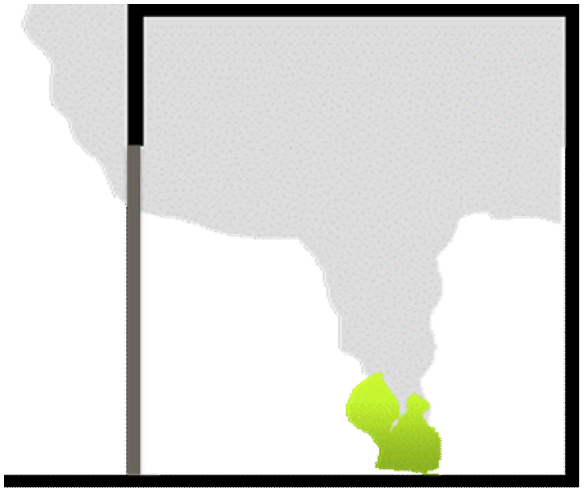


- Can the overpressure prevent one from opening the door?
- Can the smoke spread through ventilation network?
- Can the overpressure challenge structural integrity?
- How does the envelope air-tightness affect the pressure?
- How can we study these effects with numerical simulations?

The project

Report by end of 2016

Partners

- Aalto University
- Stravent Oy
- Southwest Finland Rescue Service
- Markku Kauriala Oy
- VTT Technical Research Centre of Finland Ltd.

Sponsors

- Finnish Fire Protection Fund
- Hagab AB
- Criminal Sactions Agency
- Ministry of Environment

Research path

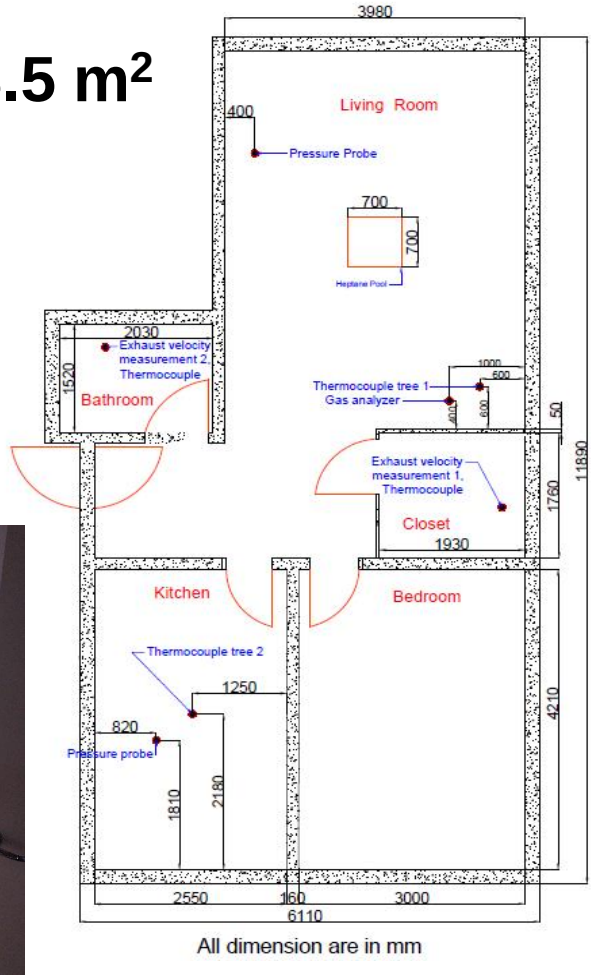
1. **Experiments**
2. **FDS validation**
3. **Case studies**
   A. Prison
   B. Aparment building

Additionally: Simple method for pressure calculation (assuming you know the temperature development, i.e. energy balance.)

Fire experiments

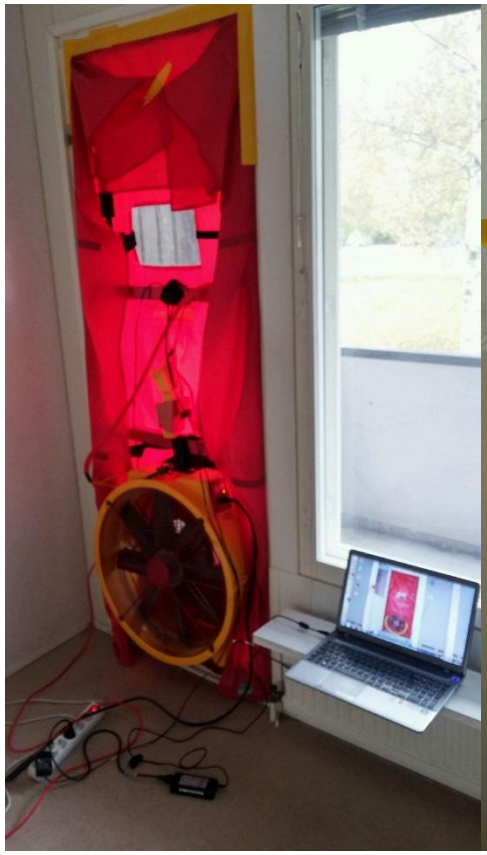
- **3-storey apartment building in Kurikka, western Finland**
- **Built in 1970's.**
- **Windows renewed few years ago.**
- **Tests in a 1st floor apartment**

58.5 m²



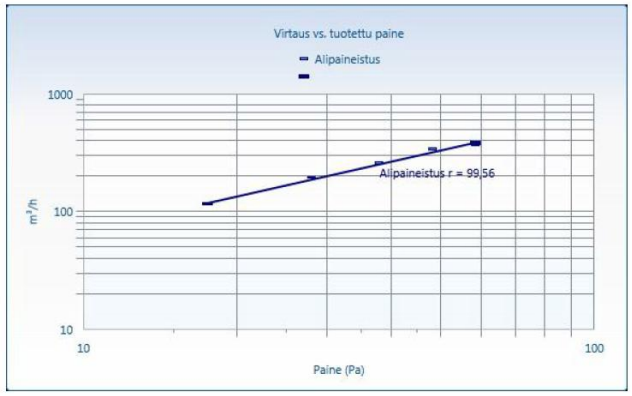
Air tightness measurements

SFS-EN 13829, Mikko Yli-Piipari / Vertia Oy



Underpressure
Q_{50} = 1.8 m^3/hm^2

Overpressure
Q_{50} = 2.7 m^3/hm^2



Ventilation configurations

CLOSED **OPEN** **NORMAL**

Fire loads

Group 1 (10 tests)

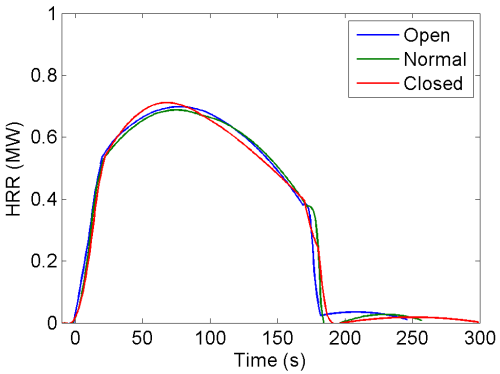
3 L n-heptane

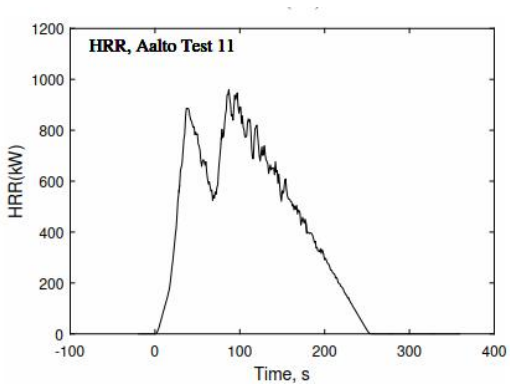
0.7 m x 0.7 m pool

Group 2 (3 tests)

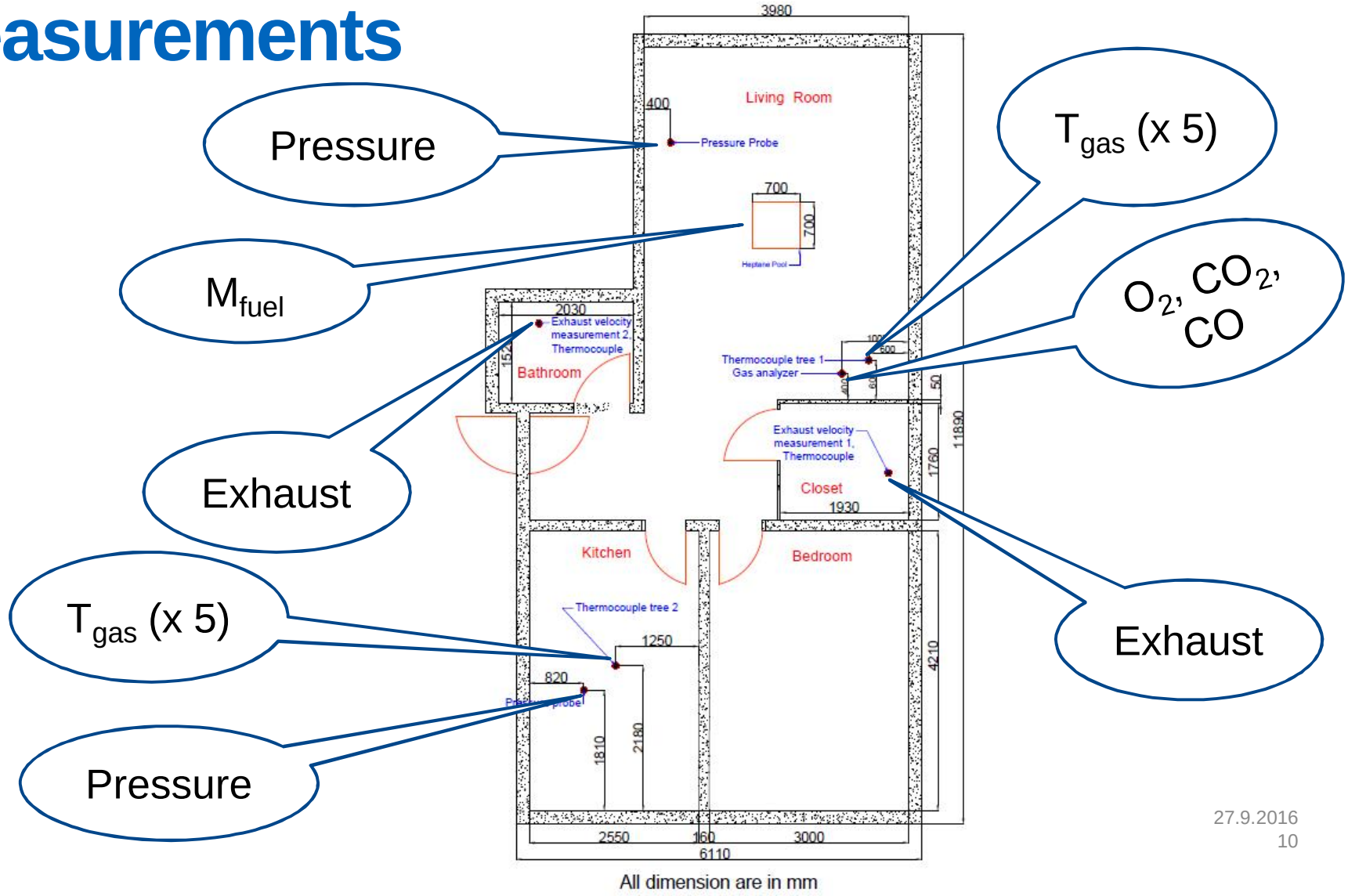
PUF matress of about 3 kg

Both fires were ultrafast (t_g < 75 s)



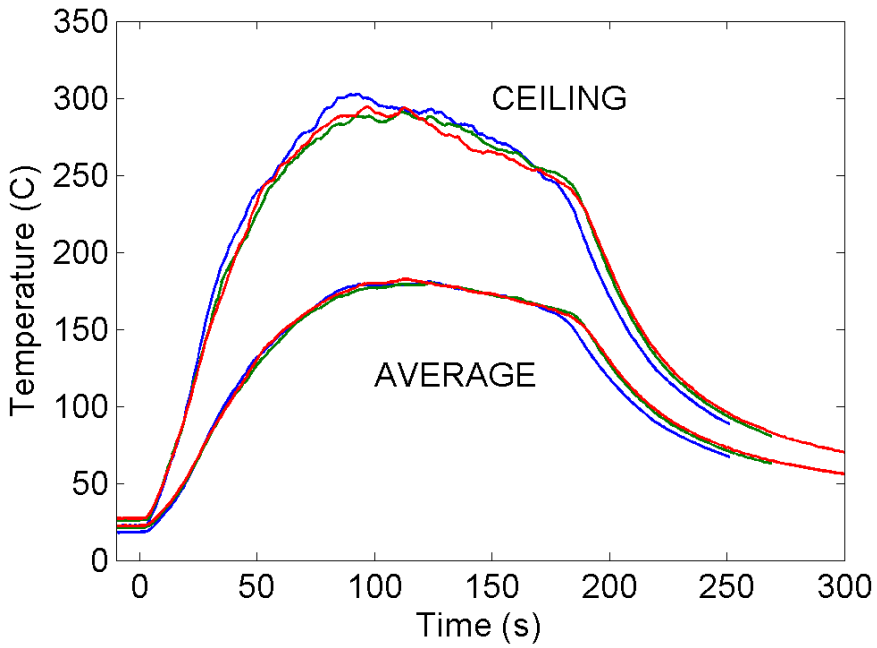


Measurements

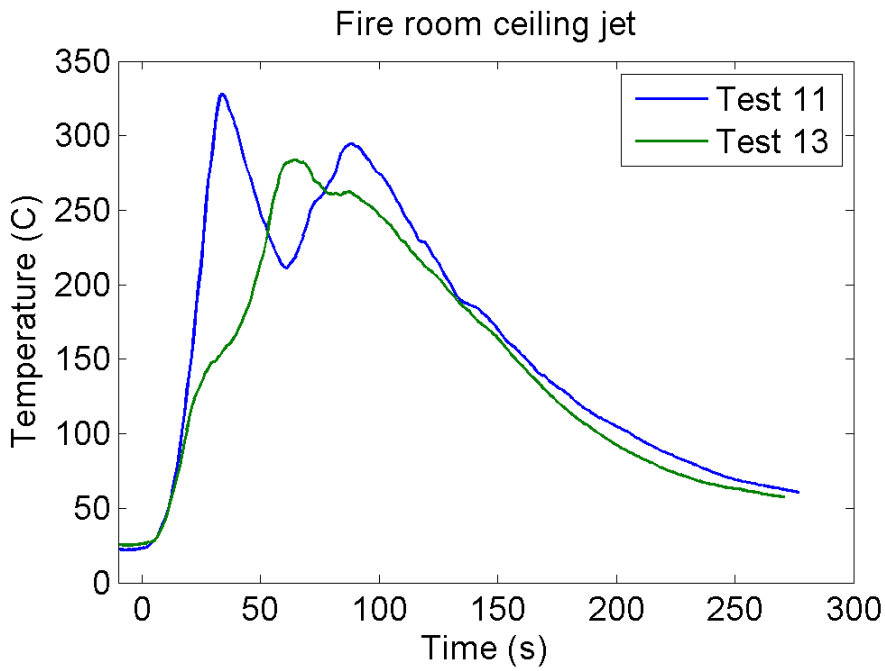


Gas temperatures

Heptane fires

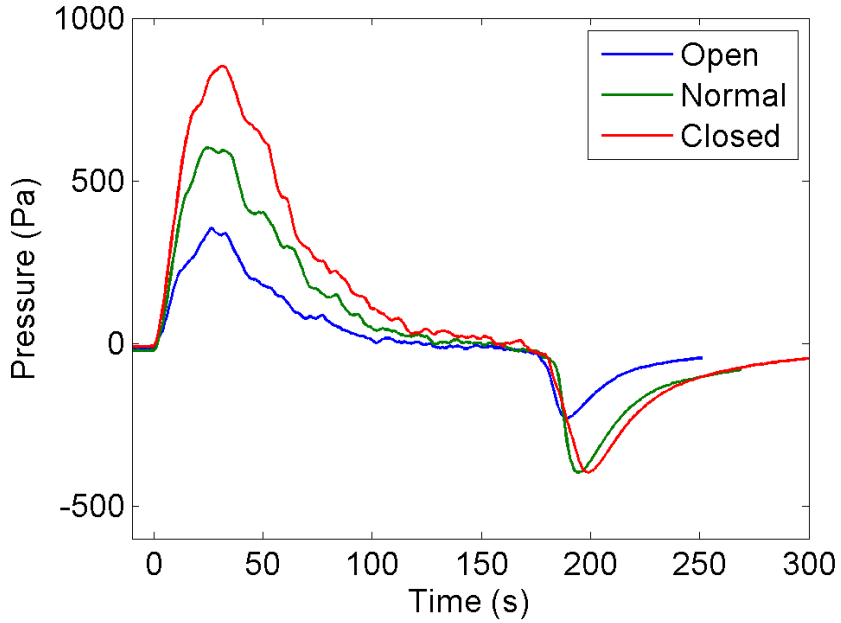


PUF fires

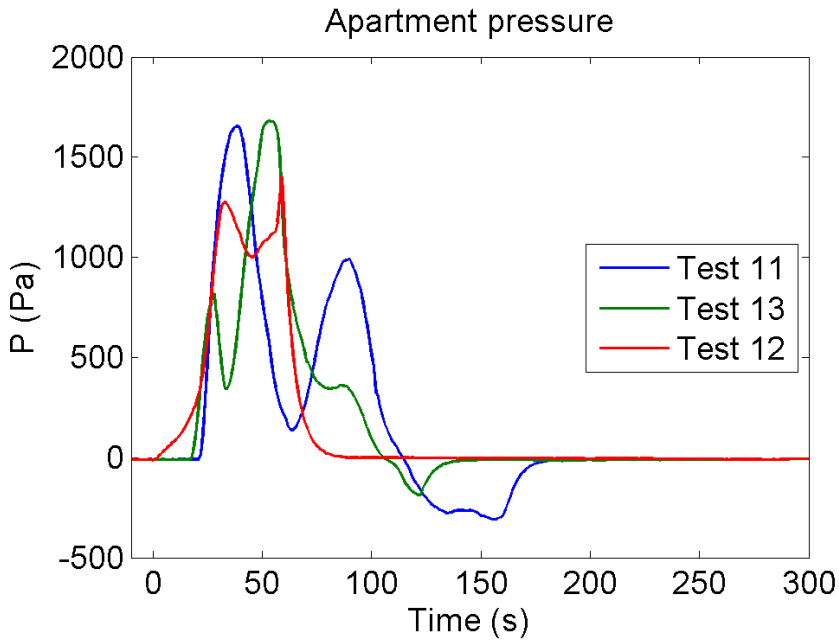


Gas pressure

Heptane fires



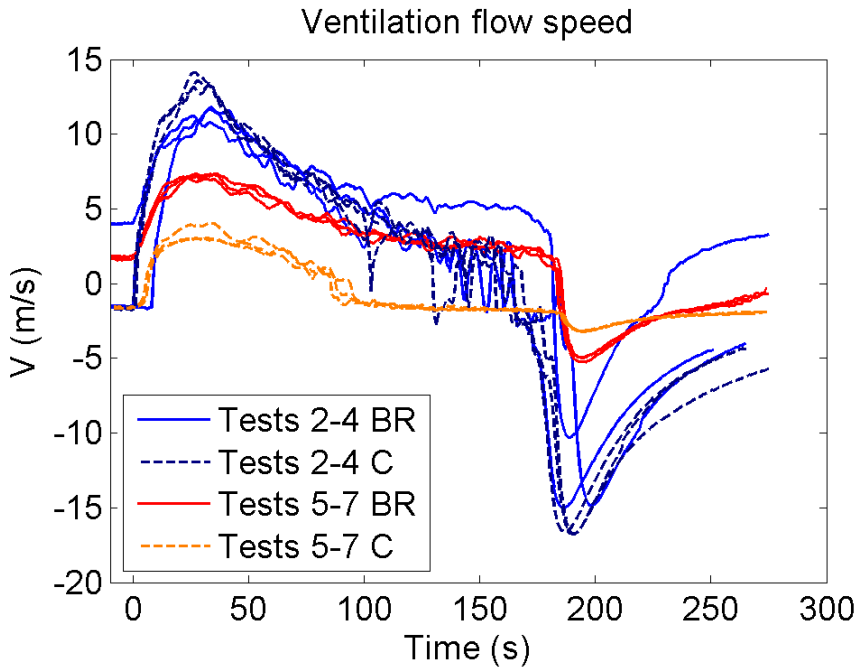
PUF fires



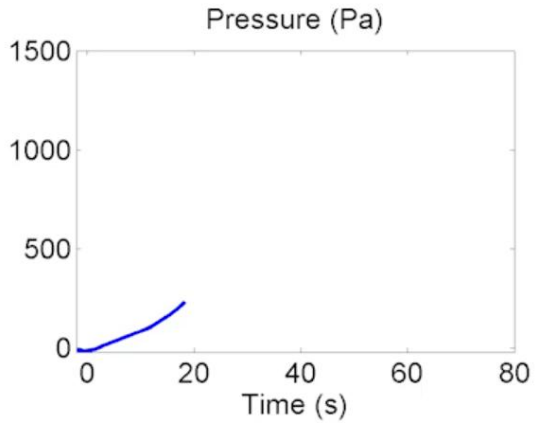
Flow speed in exhaust duct

Test 2-4: OPEN
Test 5-7: NORMAL
BR = bathroom
C = closet

Heptane pool fires



PUF in closet, normal ventilation



Test 12 observations

Fire pressure pushed out the window frame.

At failure, *P* = 1400 Pa, but earlier the light-weight wall had been exposed to 1650 Pa pressure, and it was seen to move.

General observations

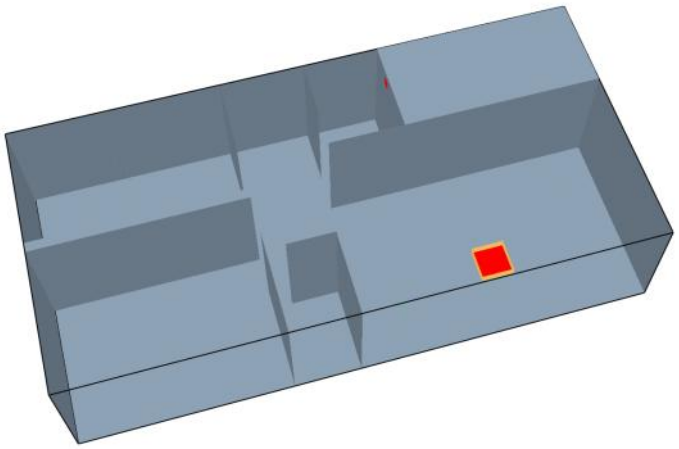
1. Liquid pool fire overpressures 300-900 Pa, depending on the ventilation configuration.
2. PUF fire overpressures up to 1600 Pa, causing mechanical failure of light-weight structures.
3. Pressure increased for 30 – 60 s, followed by gradual decay towards zero.
4. One cannot open the inner door during the first minute.
5. Fuel burn-out was followed by underpressure peak.
6. Ventilation flows followed the pressure.

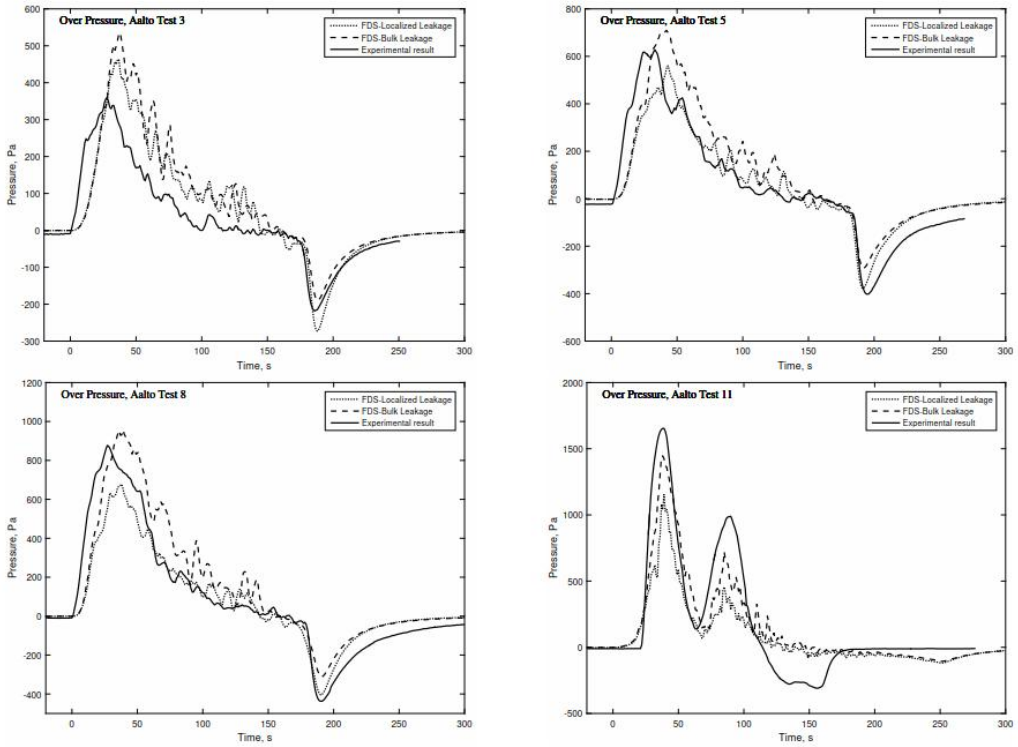
https://blogs.aalto.fi/fire/pahahupa/

Pasi Paloluoma	Peter Biström	Jere Heikkinen	Simo Hostikka	Ville Heikura	Rahul Kallada Janardhan	Tomas Fagergren	Knut Lehtinen
SWF Rescue Service	Stravent Oy	VTT ES Oy	AALTO	VTT ES Oy	AALTO	Brandskyddslaget	SWF Rescue Service

Validation of FDS modelling

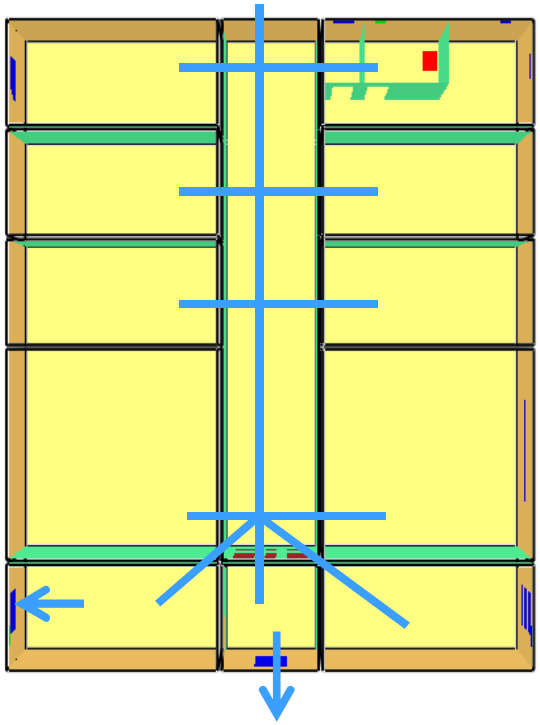
Fire Dynamics Simulator
Prescribed HRR





Case study: Apartment building (1)

Fire ”room” 50 m^2



Three air-tightness levels

1. Traditional: q50 = 3.0 m^3/m^2h
2. Normal: q50 = 1.5 m^3/m^2h
3. Near-zero: q50 = 0.75 m^3/m^2h

HRR either experimental or $Q = Q_o(\frac{t}{t_g})^2$

Ventilation network

Damper configurations:

1. No dampers
2. Only inlet branch closed
3. Both inlet and outlet closed

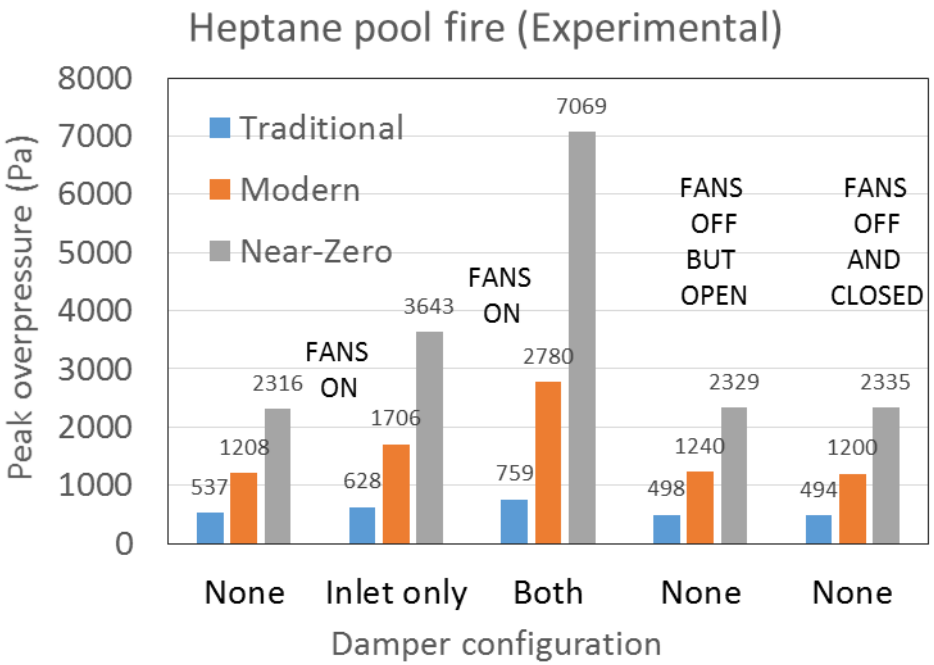
Fan configurations

1. On
2. Off and open
3. Off and outside damper closed

Case study: Apartment building (2)

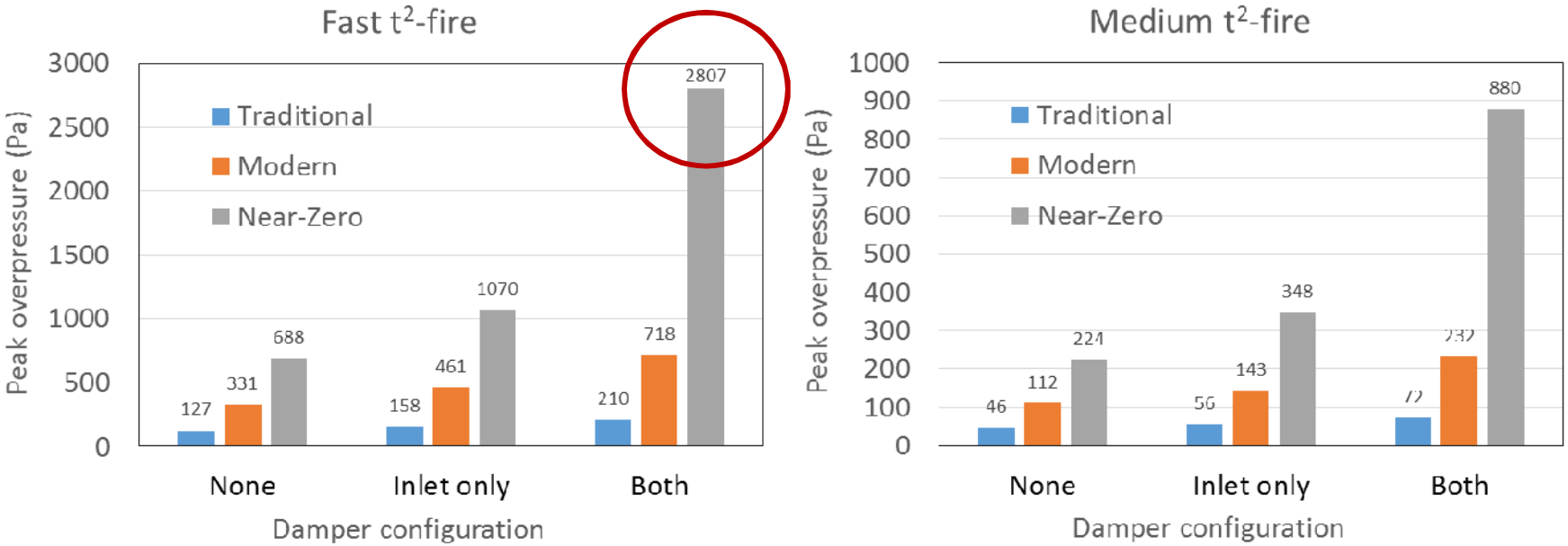
Peak overpressure when the experimental pool fire is placed in the apartment.

- **nZero building might have a structural failure even without dampers, with dampers for sure.**
- **Fan operation does not affect the peak pressures.**

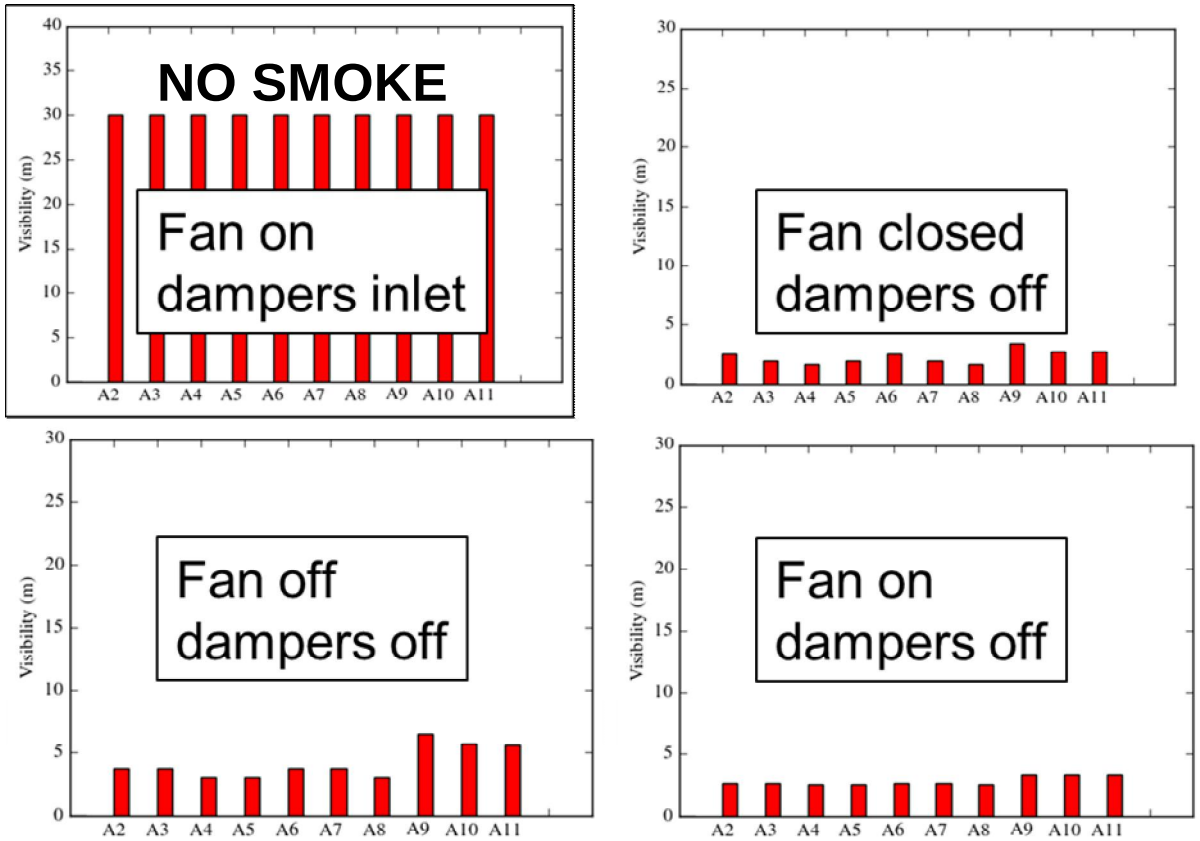


Case study: Apartment building (3)

Peak overpressures at two fire growth rates



Case study: Apartment building (4)



Minimum visibility (meters) in neighbouring apartments

- **Smoke goes to neighbours if there are no dampers.**
- **Even when fan is off due to the fan flow loss.**

Case study: Apartment building – Conclusions

Pressure

- Strongly affected by envelope air tightness and damper configuration
- Insensitive to fan operation

Smoke spreading to neighbours can be prevented

- IF both inlet and outlet are closed by dampers (high pressure), OR
- IF inlet is closed by damper and exhaust fan is maintained operating (lower pressure). This is the BEST option.

Questions and concerns

- **Air-tightness of internal walls is not regulated and thus unkown. Most likely they will leak smoke to exit paths.**
- **Sewers were not considered as leak paths in the simulations.**
- **Mechanical strength of internal structures is not known.**

- **Fire engineers do not generally know or understand the ventilation design.**
- **Ventilation designers do not generally think about overall pressure during fire.**

Acknowledgements

Experiment team

Aalto MSc students Rahul Kallada and Umar Riaz

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Sponsors