LUNDS UNIVERSITET

Fire ventilation

Not any panacea

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2nd best movie ever…?

But, which is the best movie…?

What is a fire and rescue operation?

- A phenomenon in which **one or more actions** are initiated, coordinated and implemented under the influence of one or several commanding officers, often carried out in **dynamic environments**.

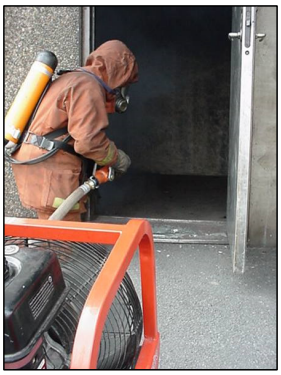
A systems perspective

- A set of interacting components forming an integrated whole
  - The characteristics of a system is different from the characteristics of its components
  - A system is more than just the sum of its components
- An example: the human body
  - The liver is a vital organ
  - We can discuss and look at the liver itself, without looking at the rest
  - But if you take out the liver from the body, it becomes pretty useless

How does this apply to fire ventilation?

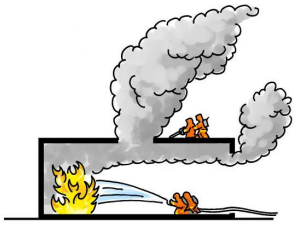
- Fire ventilation is a vital part of a fire fighting operation
- We can discuss and look at fire ventilation itself, without looking at the rest
- But if we take out fire ventilation from the operation, it becomes pretty useless

Using fans for putting out fires?



What is fire ventilation?

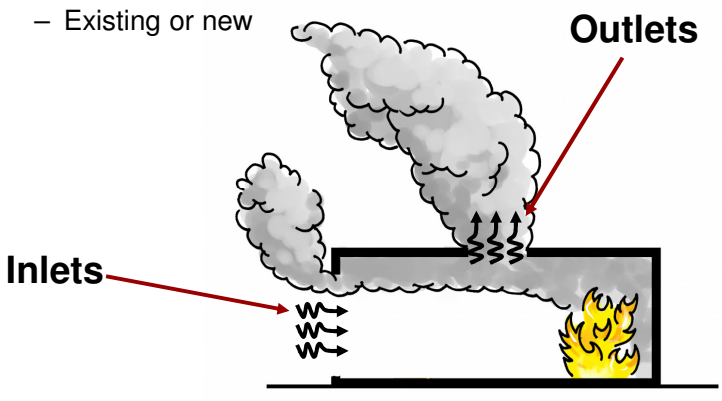
- To vent smoke or hot gases from a space exposed to fire or hot gases, in a controlled fashion!
  - To reduce the impact of heat and smoke to people and to buildings
  - To facilitate the operation
  - To stop or to limit the spread of fire and hot gases
  - To facilitate mop-up and salvage



How do we do fire ventilation?

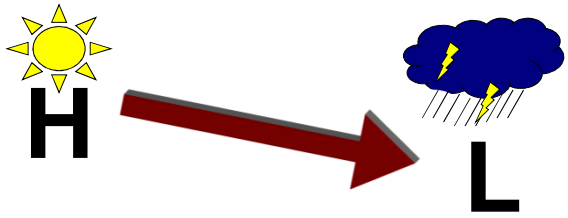
We create openings

- Existing or new

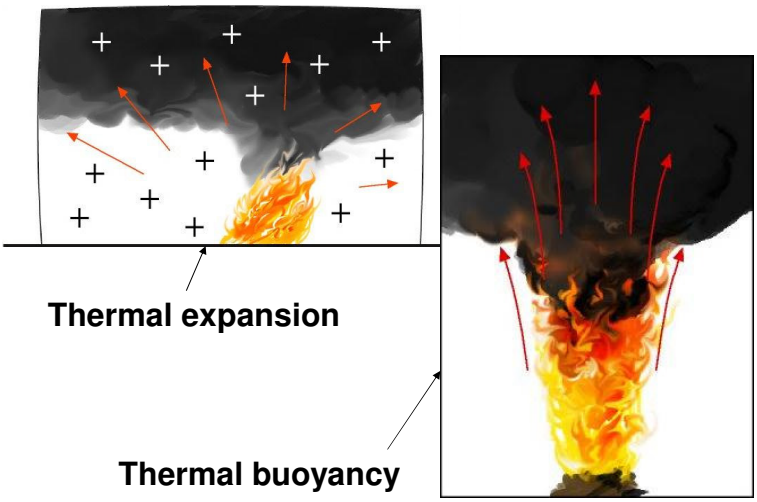


Pressure?

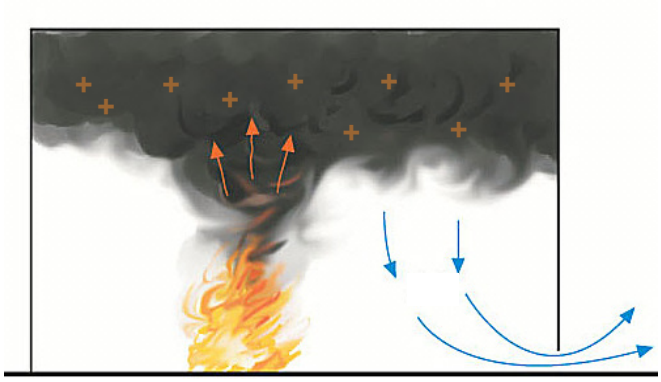
- The flow of fire gases is generated due to differences in pressure
  - From high pressure to low pressure



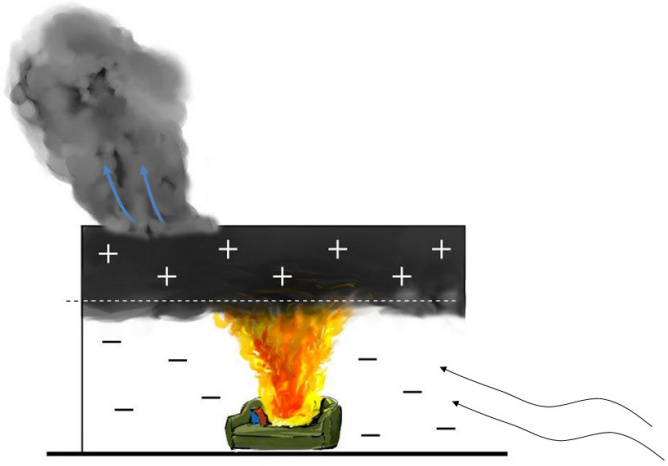
Pressures in buildings due to fire



Flow in a room with a small opening



Flow in a room with a large opening



Pressure differences creates flow

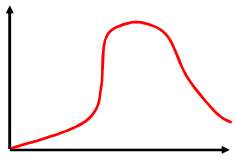
assuming there's an opening…

- There will be a flow of gases between rooms with different pressures
- There will be a flow within a single room if there are differences in pressure within the room
- The flow will be from higher pressure to lower pressure

- **Adding a fan doesn't change this!**

So, what happens when we vent?

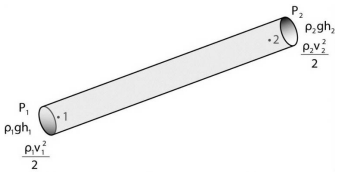
- Openings
  - Smoke and hot gases flows out
  - Fresh air flows in
- Pressure differentials in the building is changed
- Fuel control
  - No immediate/obvious/distinct influence on the fire
- Ventilation control
  - Immediate/obvious/distinct influence on the fire
  - Fire will increase its intensity
    - Increased rate of heat release
    - Rapid flame spread
    - …



- **Adding a fan doesn't change this!**

The Bernoulli equation

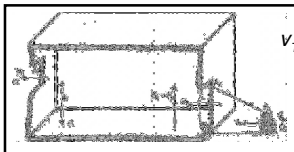
Describes the relation between pressure and velocity



First law of thermodynamics, conservation of energy, tells us that

$$P_1 + \rho_1 g h_1 + \frac{\rho_1 v_1^2}{2} = P_2 + \rho_2 g h_2 + \frac{\rho_2 v_2^2}{2}$$

Atmospheric pressure — Hydrostatic pressure — Dynamic pressure



$$v_T \cdot D_T = v_0 \cdot D_0 \quad i.e. \quad v_T = \frac{v_0 \cdot D_0}{D_T}$$

$$P_{dyn} = \frac{\rho_0 \cdot v_T^2}{2}$$

$$\dot{V}_0 = v_0 \cdot A_0 = v_0 \cdot \frac{\pi \cdot D_0^2}{4} \qquad \dot{V}_F = C_d \cdot v_F \cdot A_F$$

$$P_0 + P_{dyn} = P_1 + \frac{1}{2} \cdot \xi \cdot \rho_0 \cdot v_T^2 + \frac{1}{2} \cdot \rho_0 \cdot v_1^2$$

$$P_1 + \frac{1}{2} \cdot \rho_0 \cdot v_1^2 = P_2 + \frac{1}{2} \cdot \xi \cdot \rho_0 \cdot v_F^2 + g \cdot \rho_0 \cdot h$$

$$P_2 = P_0 - g \cdot \rho_0 \cdot h$$

$$v_T = \frac{v_F \cdot A_F}{A_T} \qquad v_1 \approx 0 \qquad v_2 \approx 0$$

$$v_F = \sqrt{\frac{P_{dyn}}{\frac{1}{2} \cdot \xi \cdot \rho_0 \cdot \left(\left(\frac{A_F}{A_T} \right)^2 + 1 \right)}} \qquad P_{dyn} = 8 \cdot \rho_0 \cdot \left(\frac{\dot{V}_0}{\pi \cdot D_0 \cdot H} \right)^2$$

$$\dot{V}_F = \frac{2.44}{\pi \cdot \sqrt{\xi}} \cdot \frac{H \cdot \dot{V}_0}{D_0} \cdot \left[\frac{\frac{A_F}{A_T}}{\sqrt{1 + \left(\frac{A_F}{A_T} \right)^2}} \right]$$

$A_F \gg A_T \rightarrow$ large

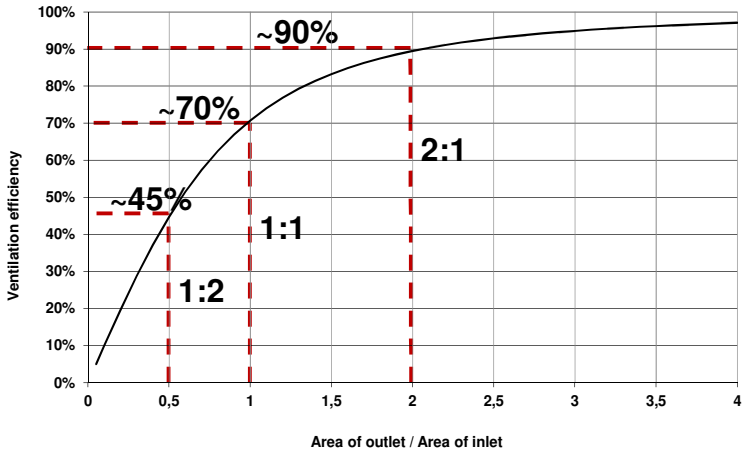
$$\frac{\frac{A_F}{A_T}}{\sqrt{1+\left(\frac{A_F}{A_T}\right)^2}}$$

X-axis

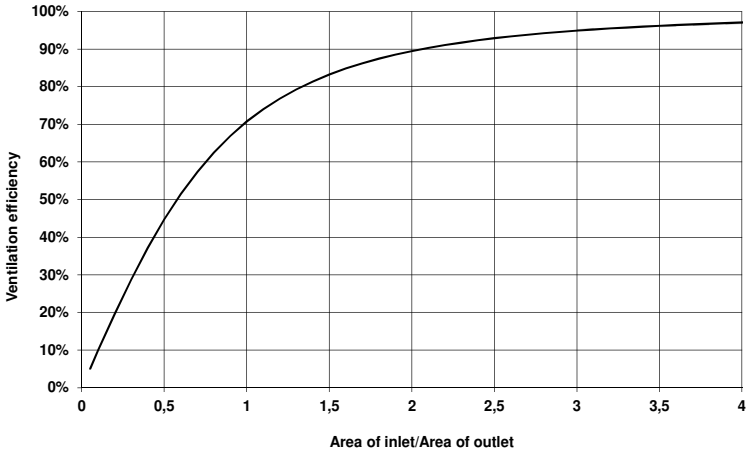
Y-axis

Ventilation factor "efficiency"

Venting, using PPV

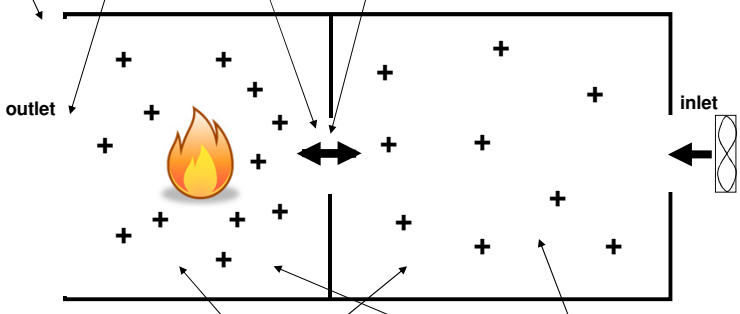


Venting, without PPV (thermal ventilation)



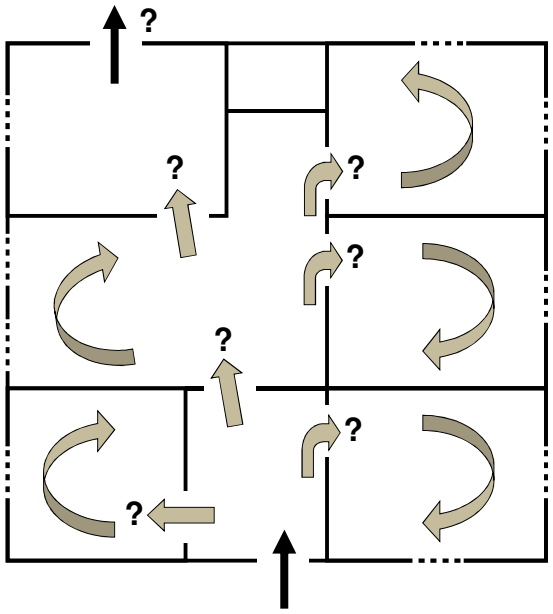
large outlet → no "backflow" due to pressure differential in the interior opening

small outlet → "backflow" due to pressure differential in outlet



pressure in the left room larger than pressure in the right room

pressure in the right room larger than pressure in the left room



Distance between inlet and fan?

- There's not really any answer
- It depends on
  - Fan size (diameter + power + …)
  - Type of fan
  - Construction of fan
  - Size of inlet
  - Lay-out of building (!)
  - …
- Consequently: you have to test every fan that you buy and learn how it works!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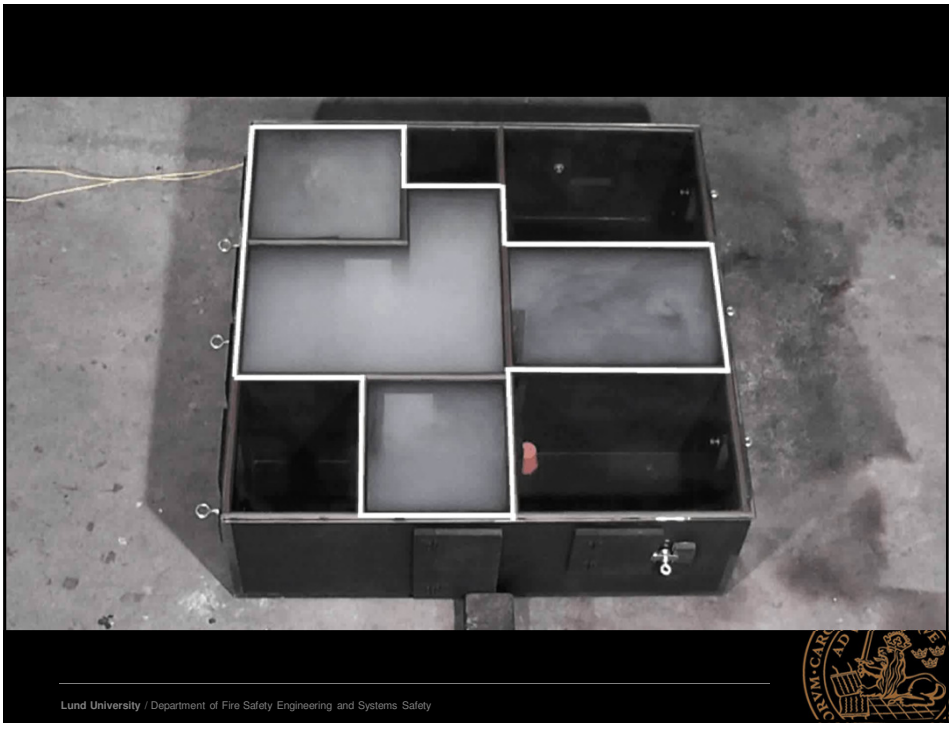
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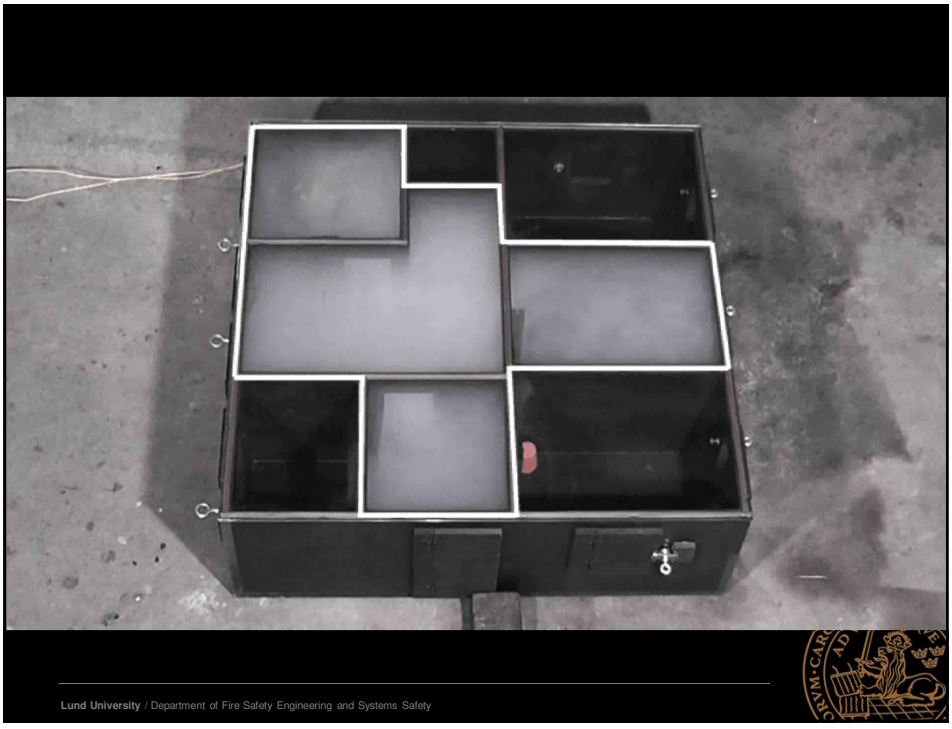
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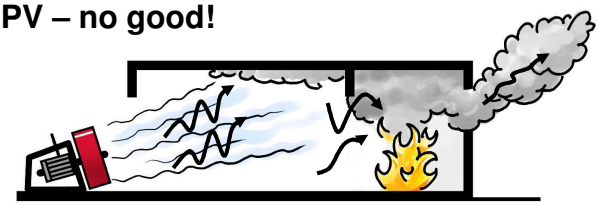
Summarizing Positive Pressure Ventilation

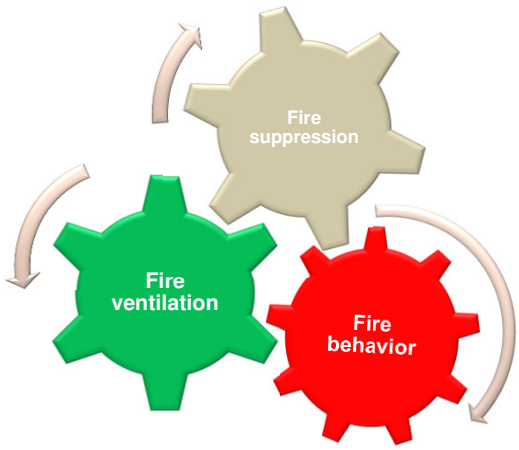
- Pressure differentials creates flow
- **Outlets** should be **at least** as large as inlets, preferably **twice as large**
- No outlet – no PPV!
- **No PPV – no good!**



Fire ventilation is not any panacea!

- Consider the options, **all** of the options!
- Coordination is the key!

An integrated approach to fire fighting operations



Thank you!

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