Tunnel Ventilation

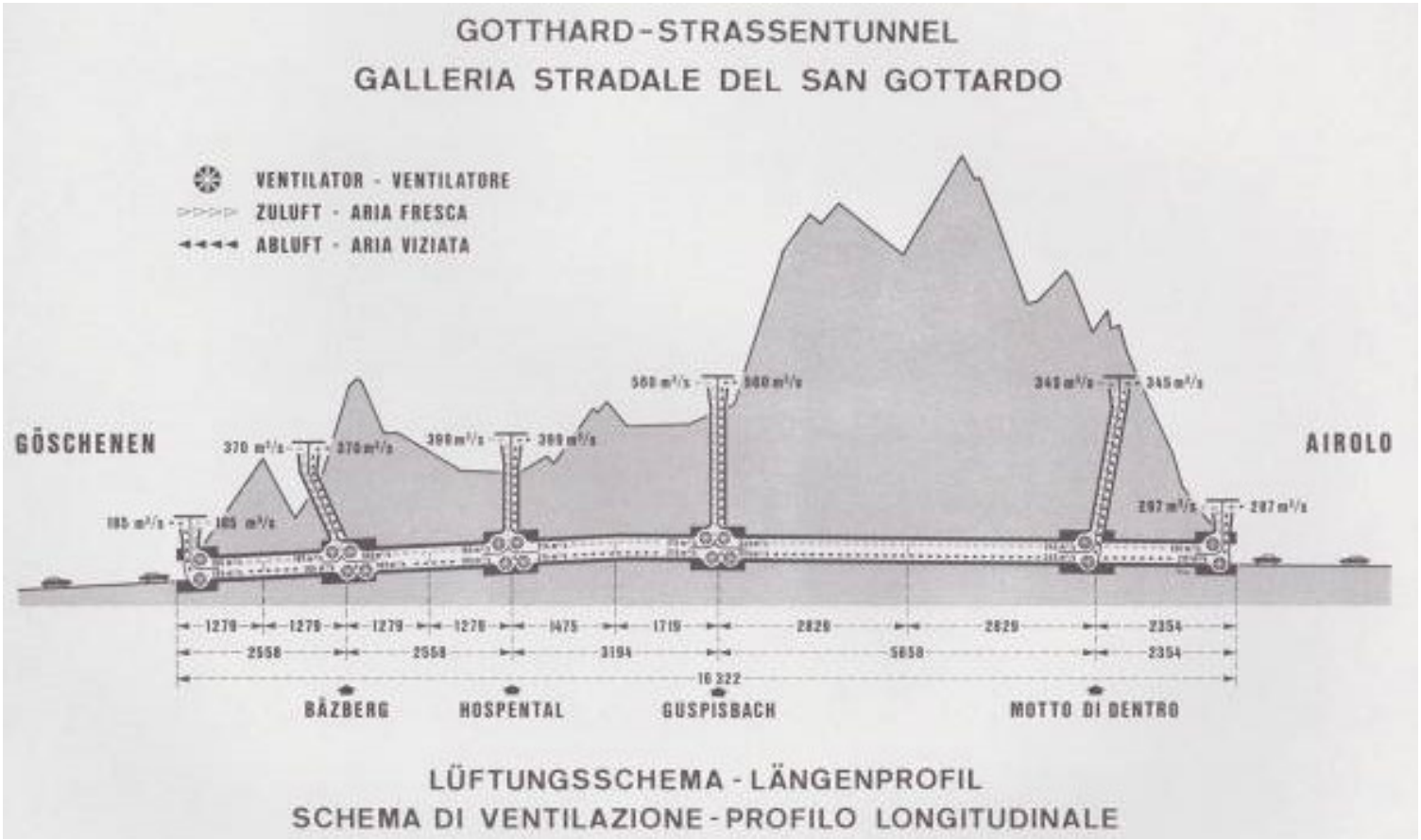
Gotthard Rail Tunnel 1882

5th International Seminar on Underground Space
Health & Safety in Underground Space
October 18th, 2019, Lisboa, Portugal

Road Tunnel Ventilation

Gotthard Road Tunnel
1980

Road Tunnel Ventilation



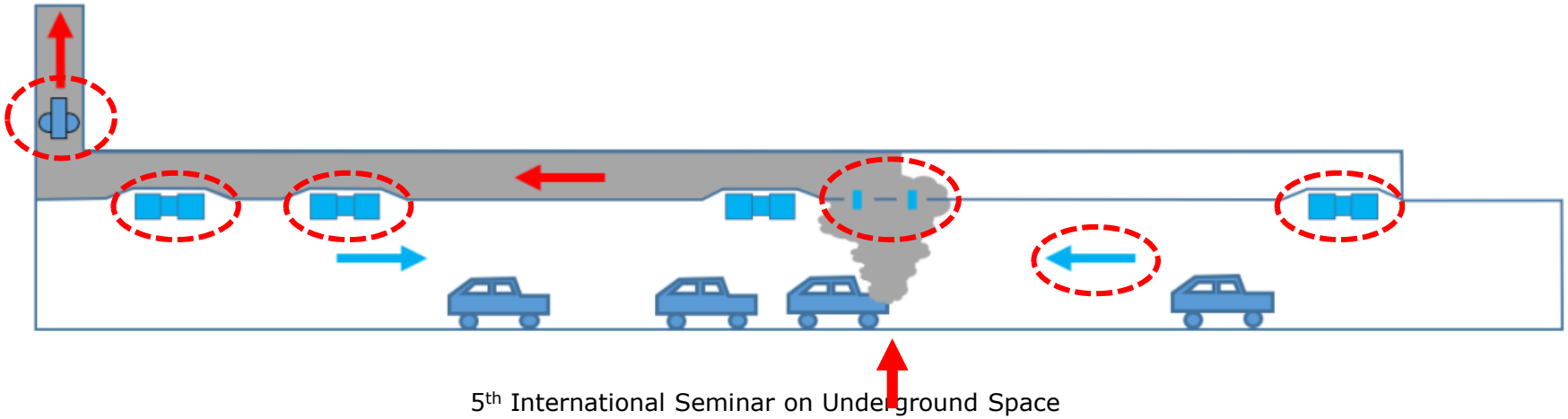
Gotthard Road Tunnel 1980

But then…

Montblanc Tunnel 1999
Tauern Tunnel 1999
Gotthard Tunnel 2001

As a consequence…

- European Directive 2004/54/EC
- National regulations
- New ventilation systems for smoke control: Local smoke extraction with smoke dampers and airflow control.



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On automatic control of longitudinal airflow in tunnels

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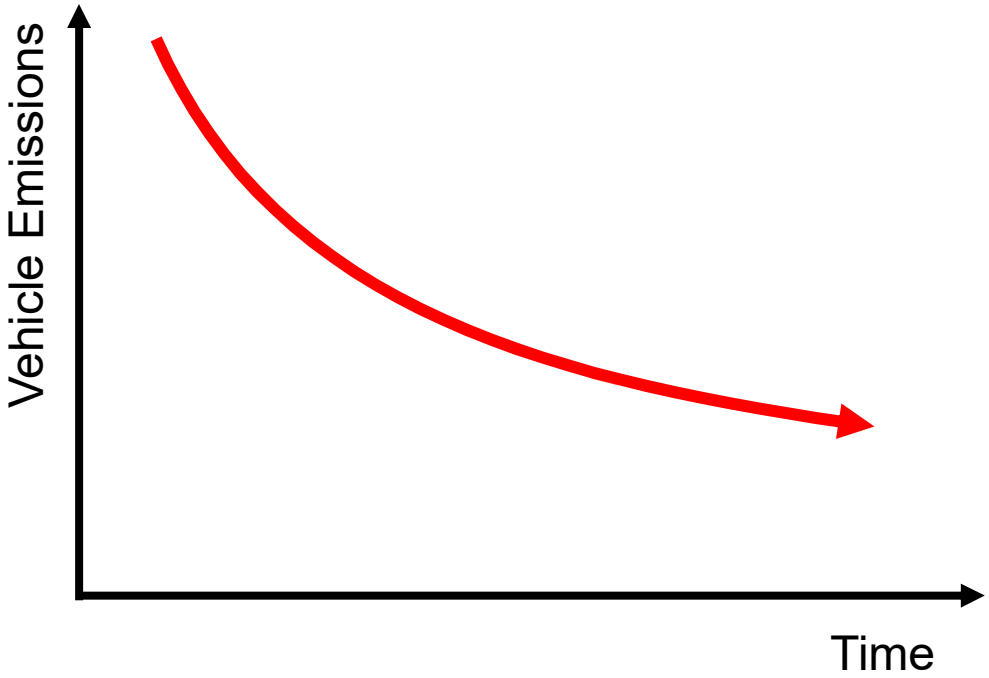
Emission Regulations

> Vehicle emissions

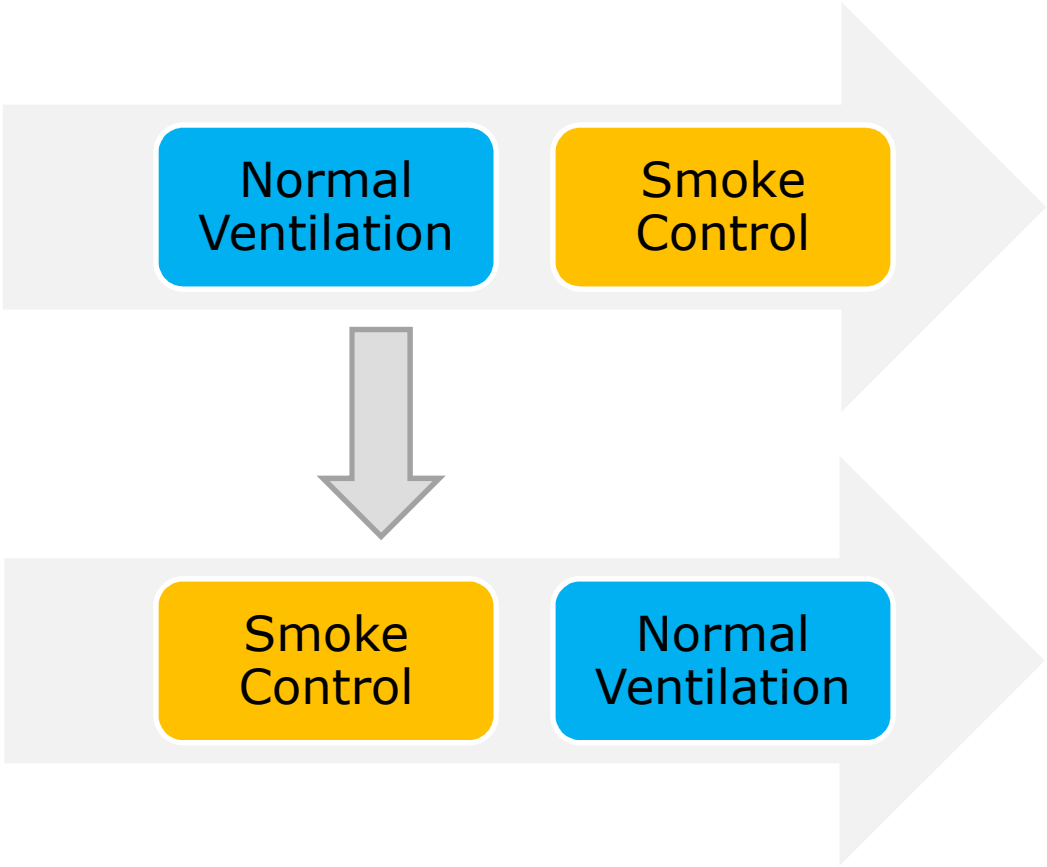
	Year of Implementation
ECE R 15/03	1979
ECE R15/04	1982
PC Euro 1	1992
PC gasoline Euro 2	1997
PC gasoline Euro 3	2000
PC gasoline Euro 4	2005
PC gasoline Euro 5	2008
PC gasoline Euro 6* **	2014



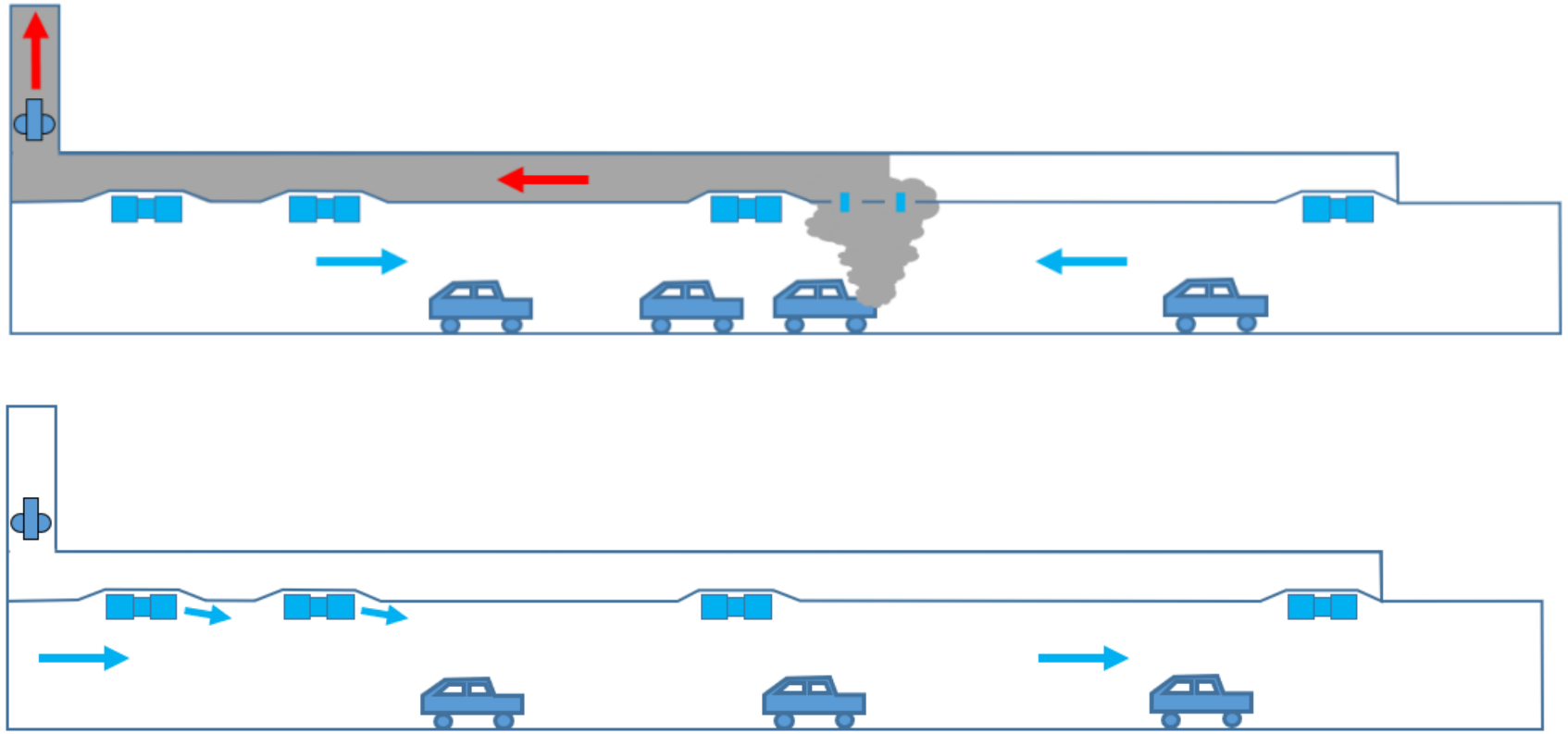
Design Process

before 1999

after 1999



Tunnel Ventilation Concept Design



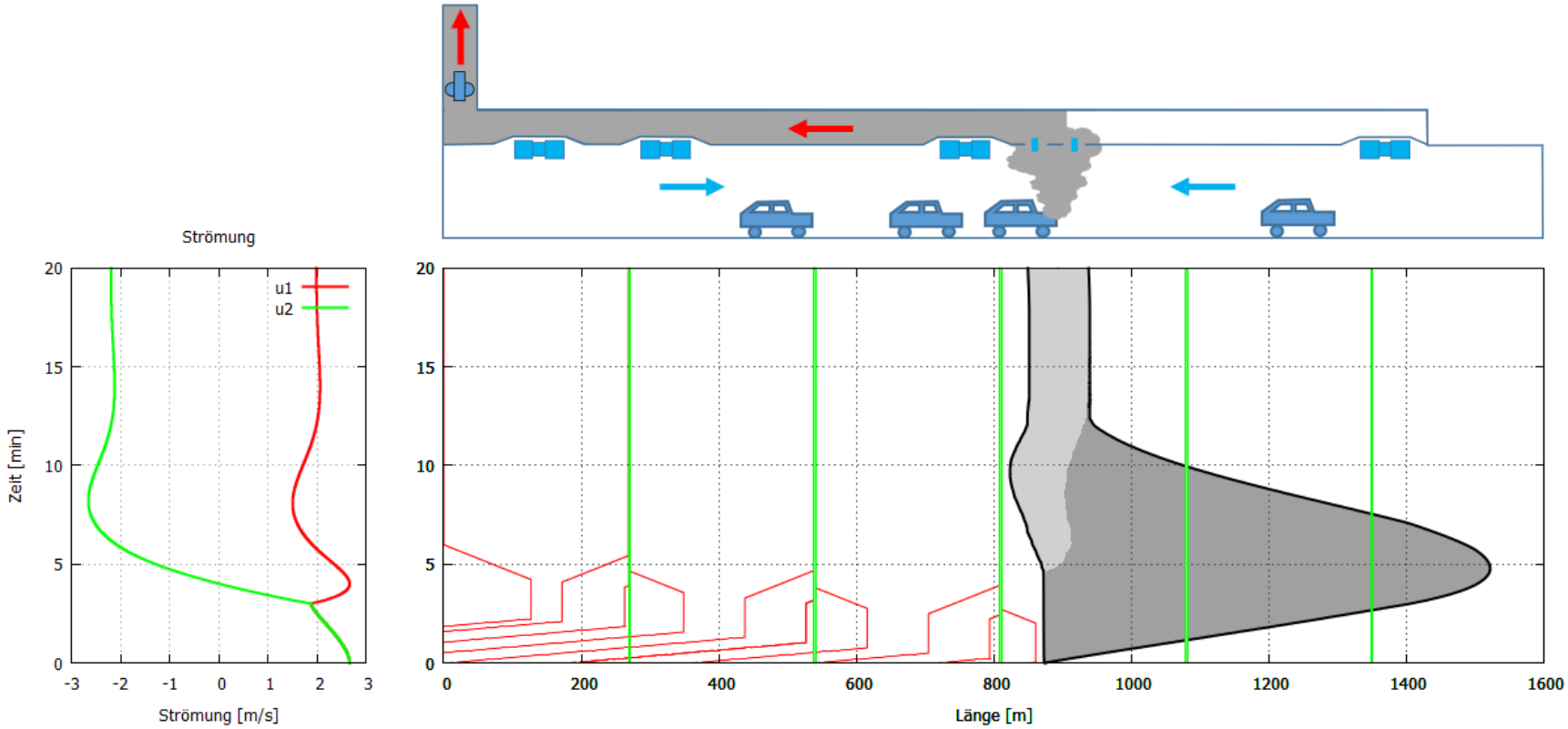
Numerical Models

> 1d numerical models

> Commercial, public or in-house

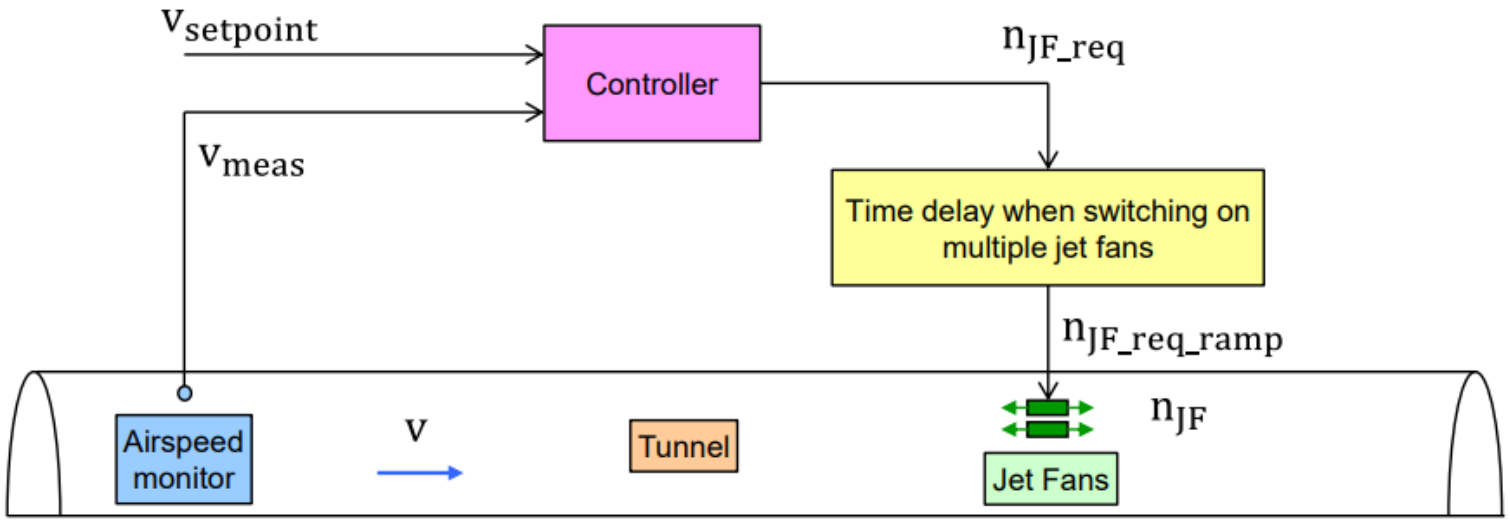
- IDA RTV Road Tunnel Ventilation, IDA Tunnel (SE), RoadTun/ThermoTun (UK)
- SES Subway Environment Simulation (US), Camatt (FR)
- TunSim, Sprint, SpitFire (CH), Numsta (AT), MFIRE (TW)
- Based on differential equations from 1960s textbooks

SpitFire



Control Criteria

> Performance
> Stability
> Simplicity



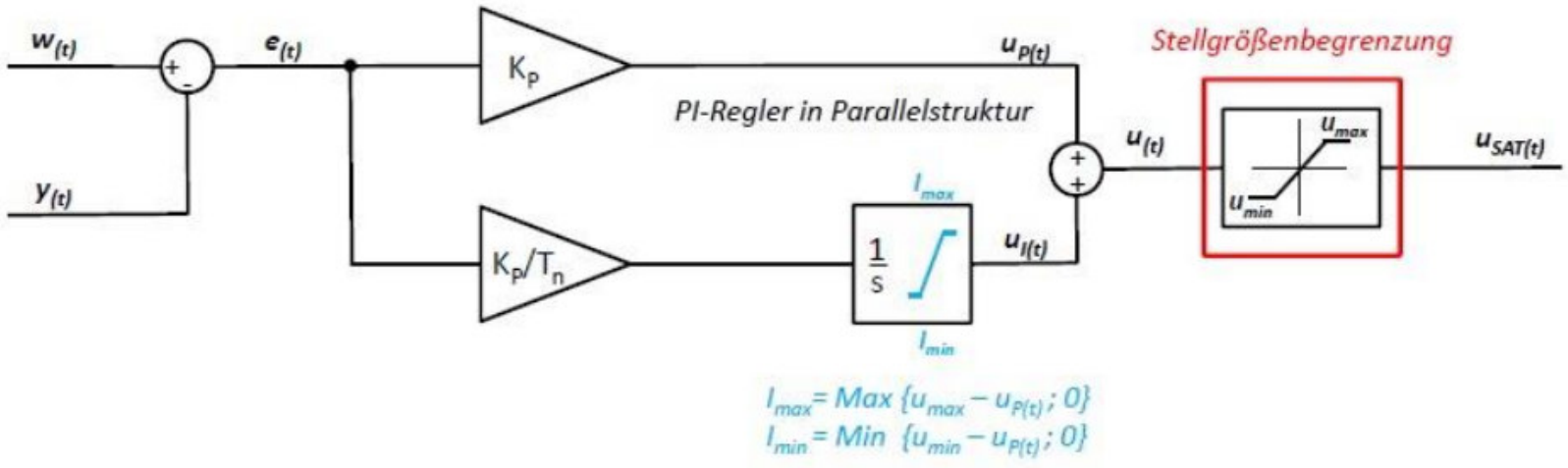
Control Approaches

> Control Tables
> P-, PI-, PID-controllers
> Model Predictive Control
> *Genetic Algorithms*
> *Fuzzy Control*

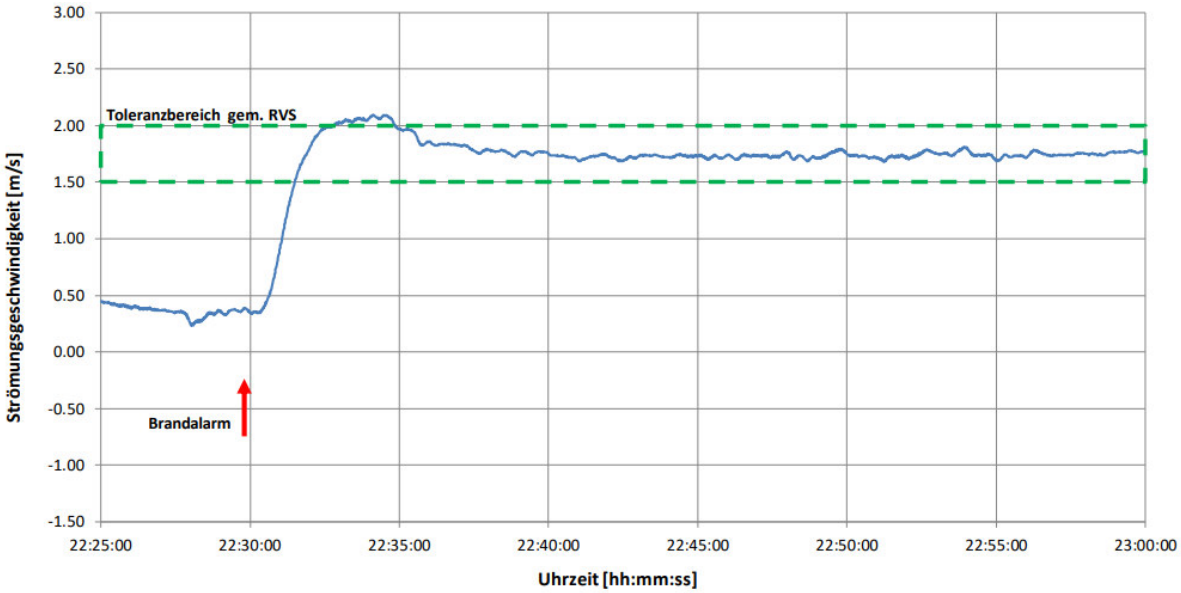
> Research Project:
Control of longitudinal airflow in road tunnels in case of fire (2013)

PI-Controller

> Performance similar to Model Predictive Control
> Standard software element
> Only two parameters



In Practice

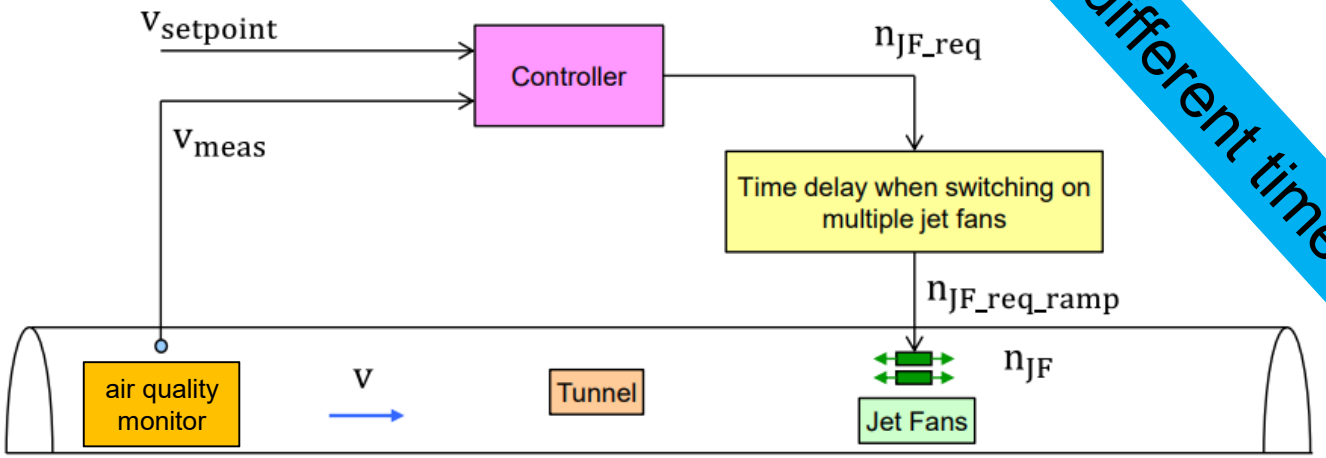

3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
Strömungsgeschwindigkeit [m/s]
Toleranzbereich gem. RVS
Brandalarm
22:25:00
22:30:00
22:35:00
22:40:00
22:45:00
22:50:00
22:55:00
23:00:00
Uhrzeit [hh:mm:ss]

PI-Control of In-Tunnel Air Quality

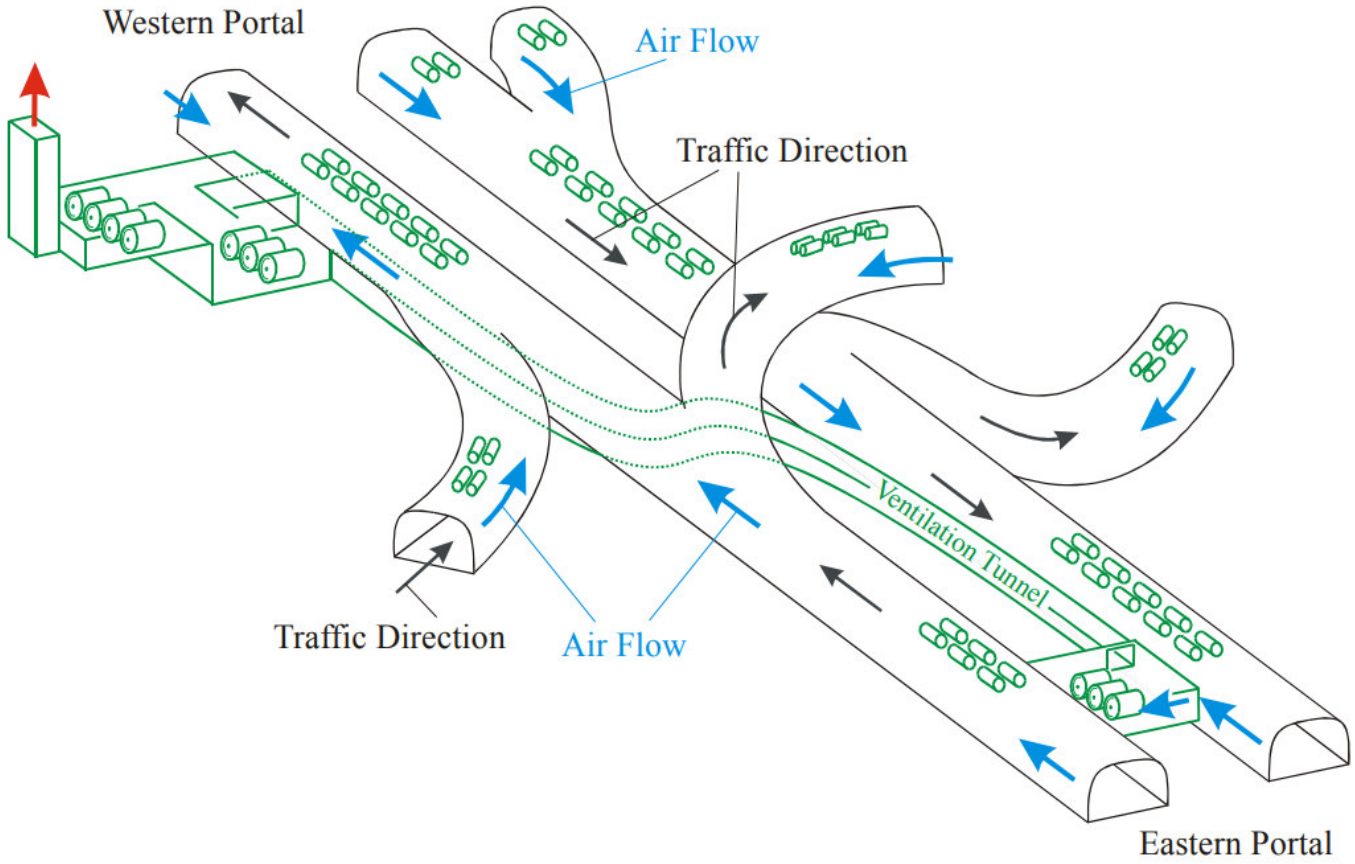
> Some design codes require dynamic control of in-tunnel air quality, e.g. by PID-controller (AT)

> This is implemented in several tunnels.

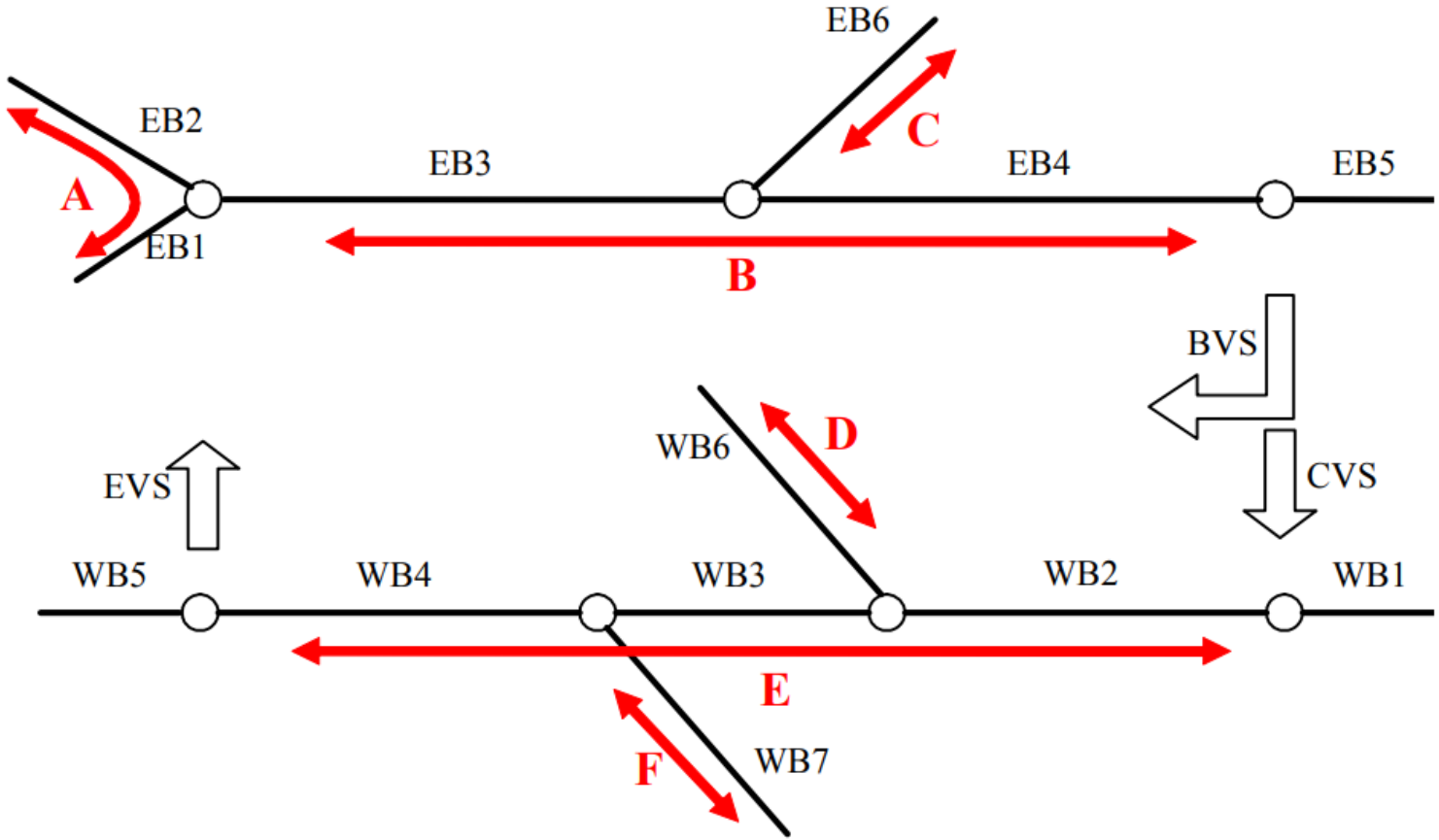
> Performance data is not available.



PI-Control of Portal Air Intake



PI-Control of Portal Air Intake



Conclusions

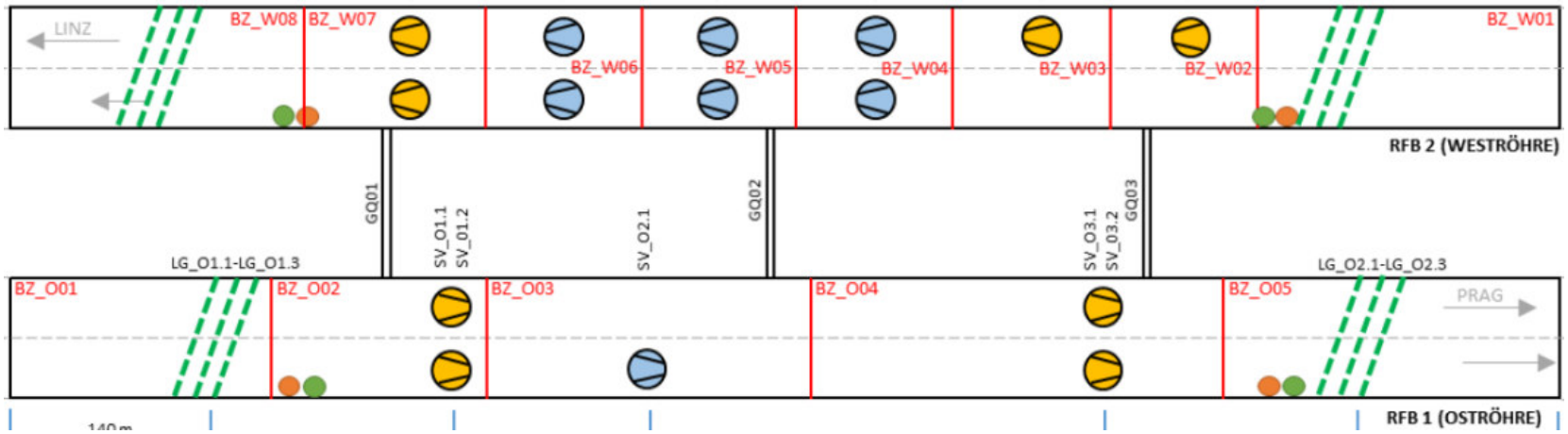
> Tunnel ventilation design based on
- Smoke control
- Normal ventilation

> Tunnel ventilation control
- Smoke control → PI-control
- In-tunnel air quality → control tables
- Portal air intake → PI-control

Everything solved?

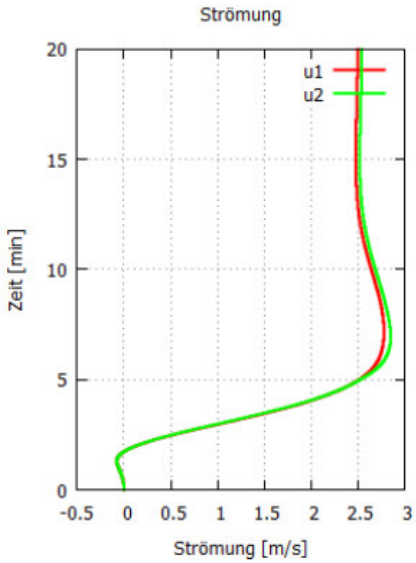
Smoke Control and Gradients

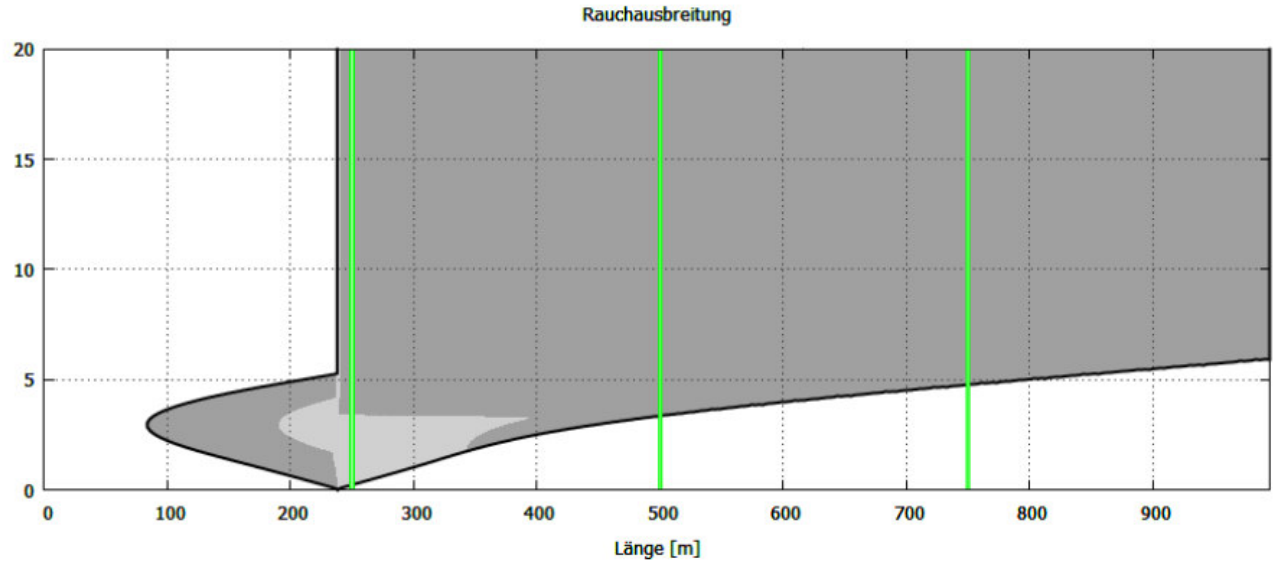
> Road tunnel, uni-directional, 1 km, 3% gradient



Smoke Control and Gradients

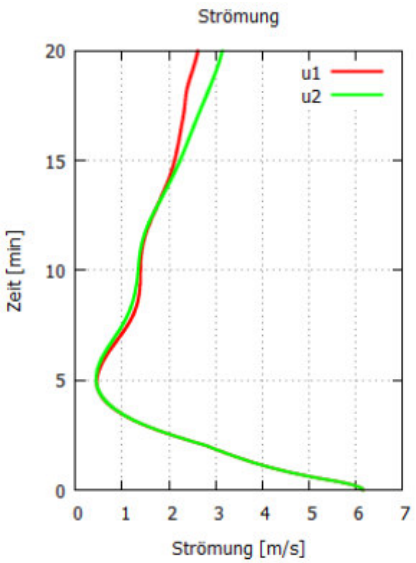
> Simulation of fire test (downhill)

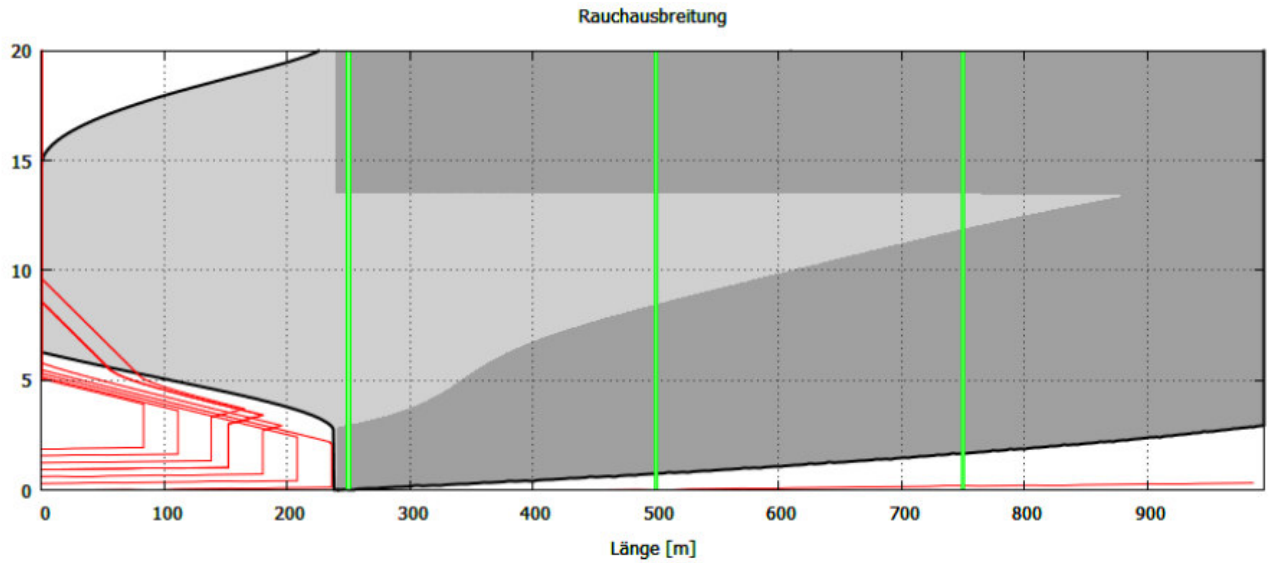




Smoke Control and Gradients

> 30 MW scenario (downhill)





Smoke Control and Gradients

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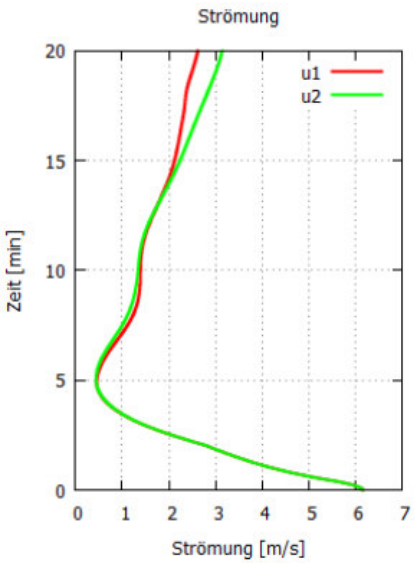

- The ventilation capacity is sufficient.
- The control parameters are correct.
- The system response is parallel to the temperature increase (buoyancy).
- The system response is lagging behind.
- The fire is an unknown quantity.
- Any ideas?

Conclusions

> There is still room for improvements

> Control if you must

> Keep it simple

Thank you