

# Challenges for Ventilation in Complex Tunnels

Examples from Urban and Mountainous Areas

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## Ventilation - background

- Ventilation plays a key role for a safe operation of a tunnel.
- Clear guidelines for design and operation of ventilation systems are given in various international publications, like PIARC, but also on national level (e.g. RVS 09.02.31/32, Austria).
- Very often, however, special boundary conditions given by geological conditions in mountainous areas or existing buildings and other structural constraints in built-up areas force special solutions for ventilation systems that deviate significantly from standardized specifications

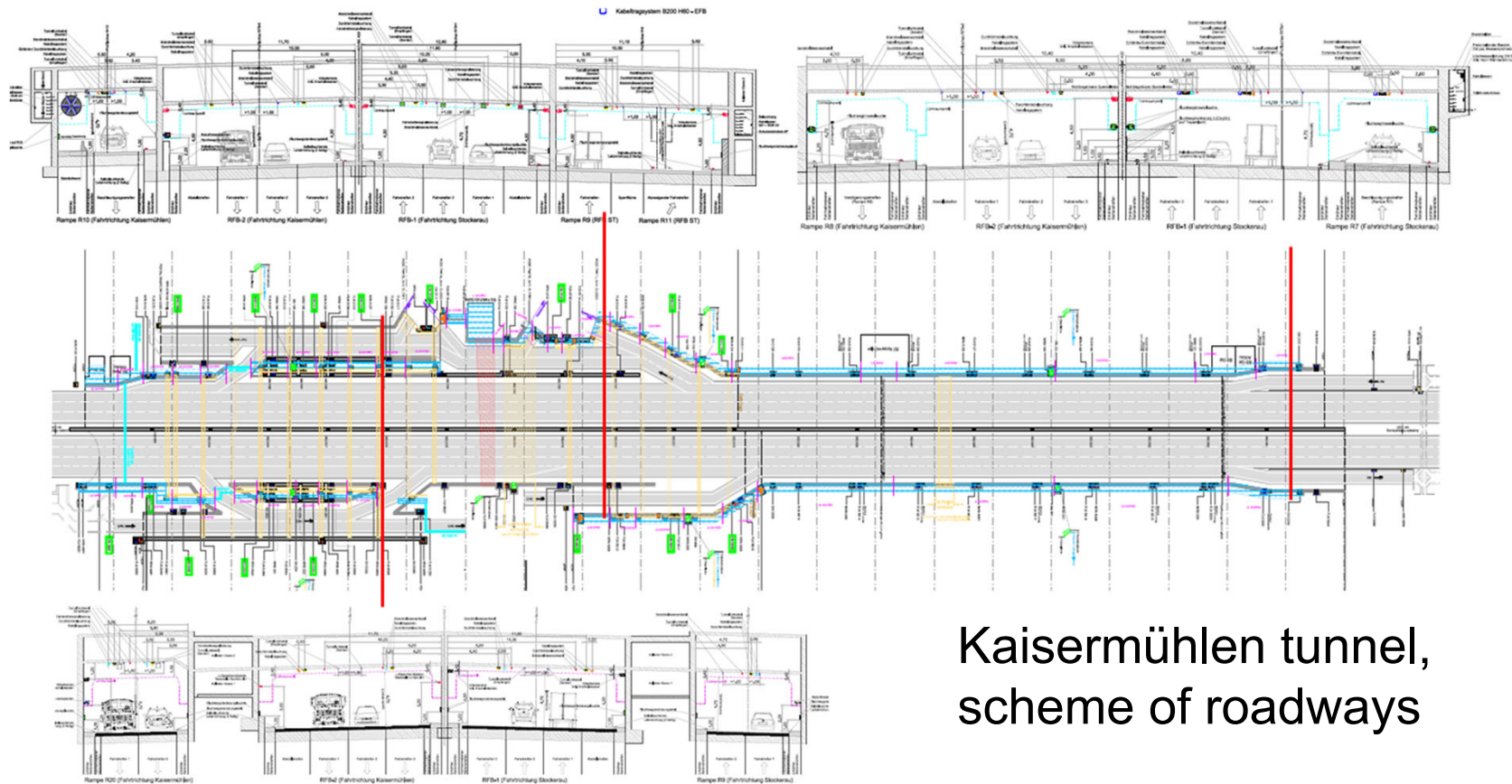
## Ventilation - background

- New projects must follow the state of the art, i.e. the currently valid guidelines
- Retrofitting of existing systems is made considerably more difficult by the fact that current safety requirements have to be applied to existing structures ....as close as possible.
- Two examples for upgrading road tunnels:
  - Arlberg road tunnel (A), 15.5 km long single tube tunnel, bidirectional traffic
  - Kaisermühlen tunnel, Vienna (A), 2.2 km long heavily trafficked tunnel, retrofitting under operation

## Kaisermühlen tunnel, Vienna (A)

- Part of the city highway system in Vienna
- >116,000 veh/day, uni-directional traffic, congestions quite frequent
- Tunnel length 2.2 km, up to 6 lanes per tube
- 10 extra on/off ramps
- 2 connections to adjacent tunnels
- Major part of the road network within the city but also for transit
- No restrictions for dangerous goods vehicles
- Refurbishment done under operation

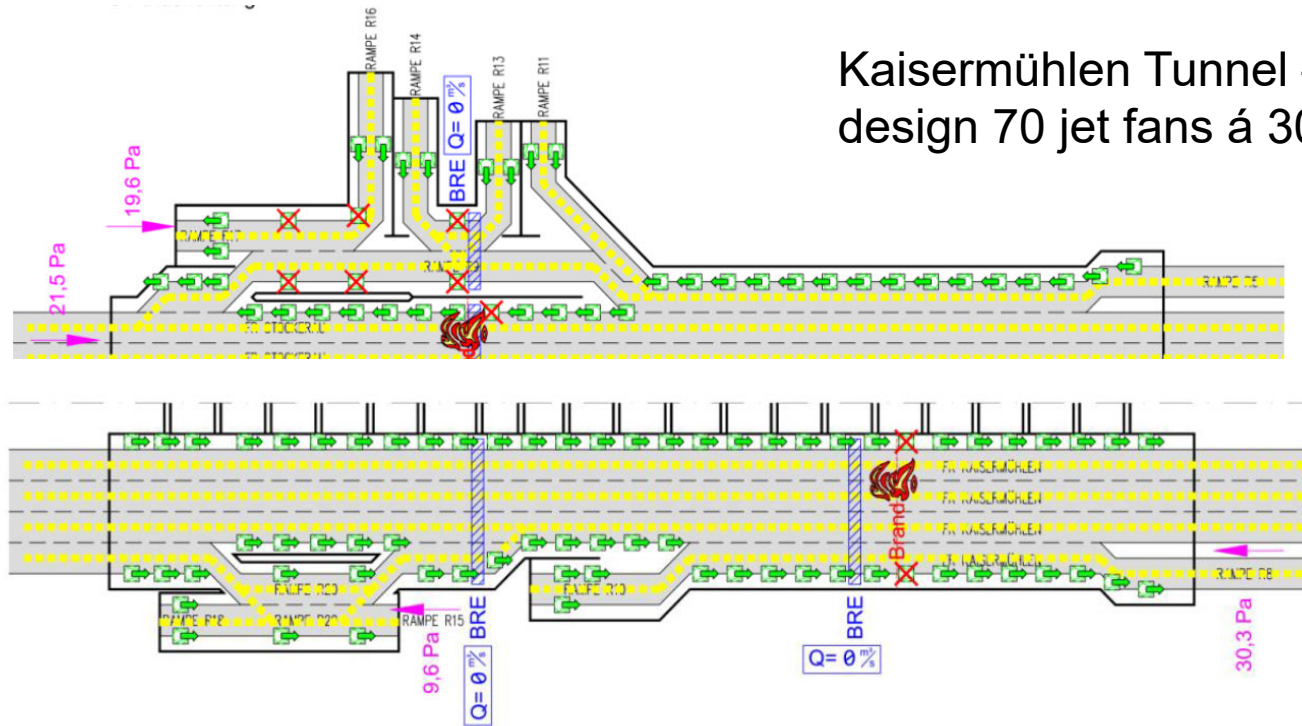




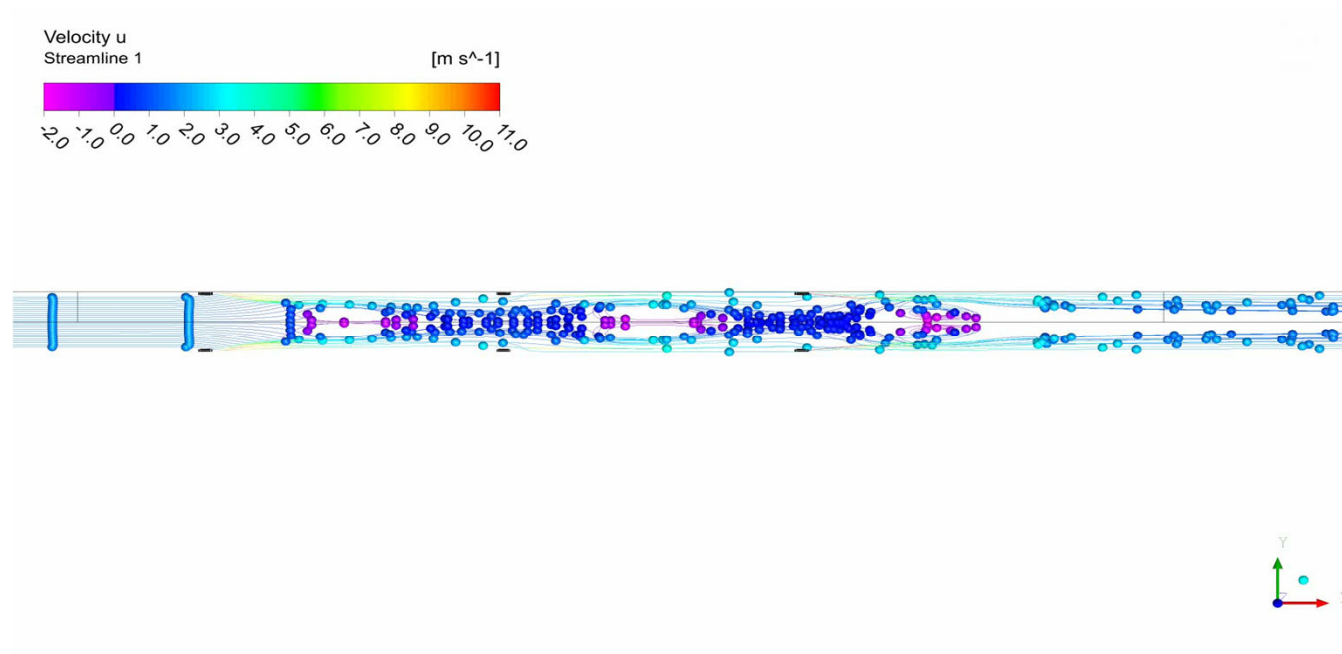
Kaisermühlen tunnel,  
scheme of roadways



## Kaisermühlen Tunnel – original design 70 jet fans á 300N

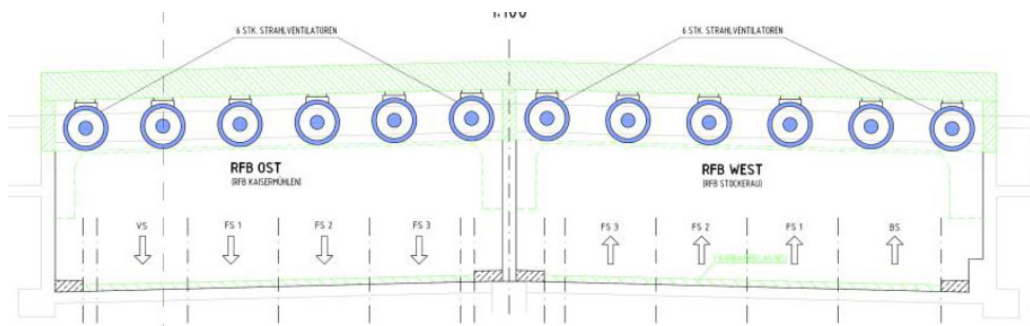


## Kaisermühlen tunnel, old design - partial air recirculation



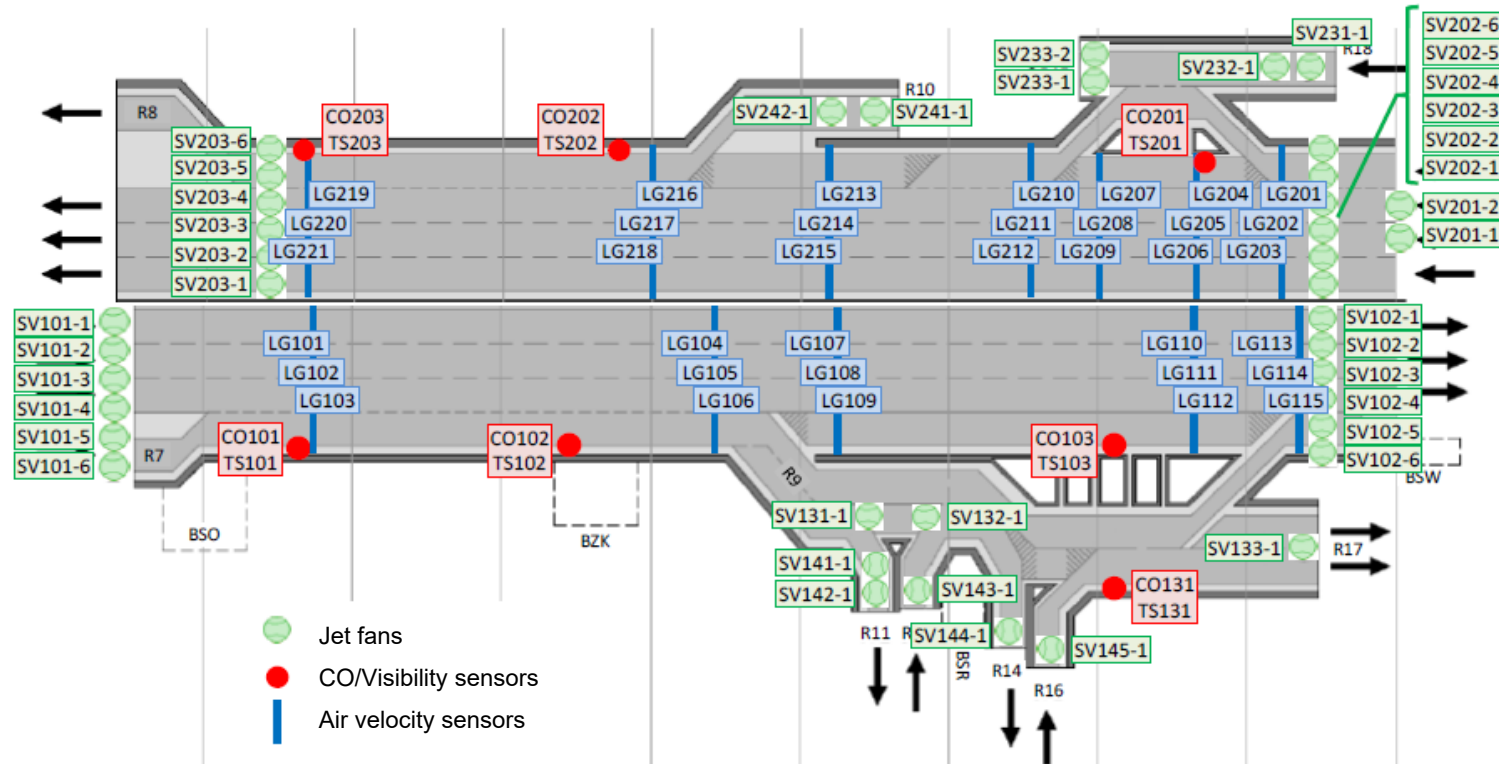


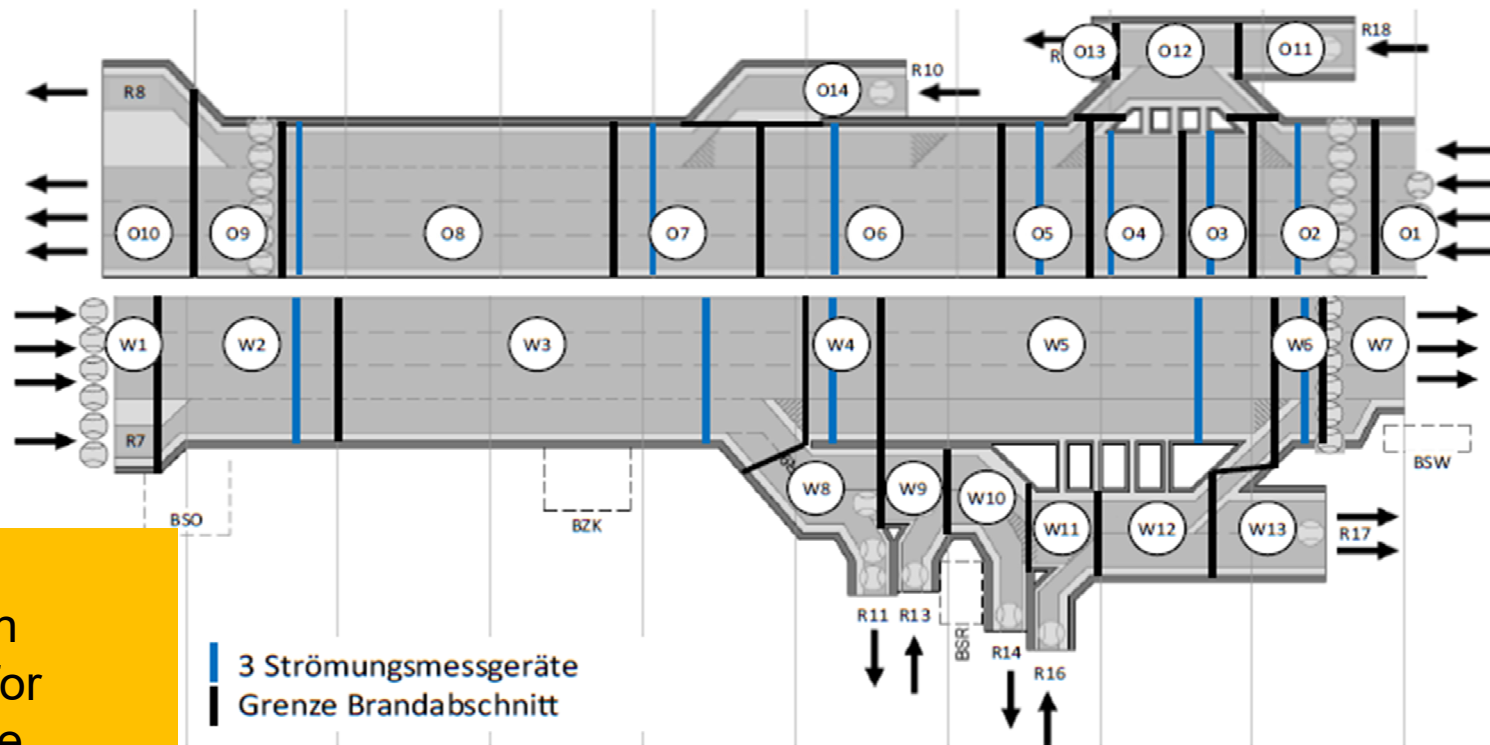
- Longitudinal ventilation with jet fans
- Existing tunnel (1990), quite small space for fans, 70 small fans (300 N) per tube
- Refurbishment: erection of niches for fans + portal installations
- Jet fans: thrust 2000 N, 1.6 m outer diameter, full reversible 12/14 per tube in main line



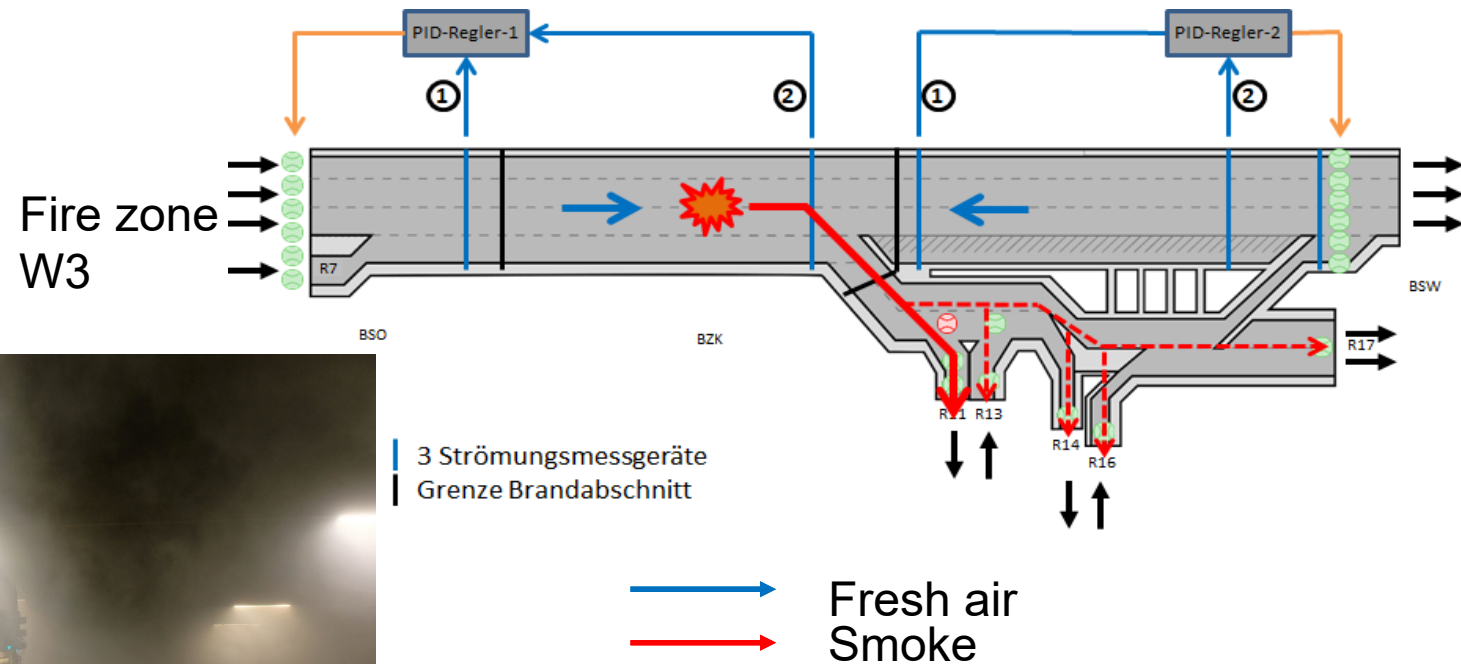


Kaisermühlen tunnel, new  
design



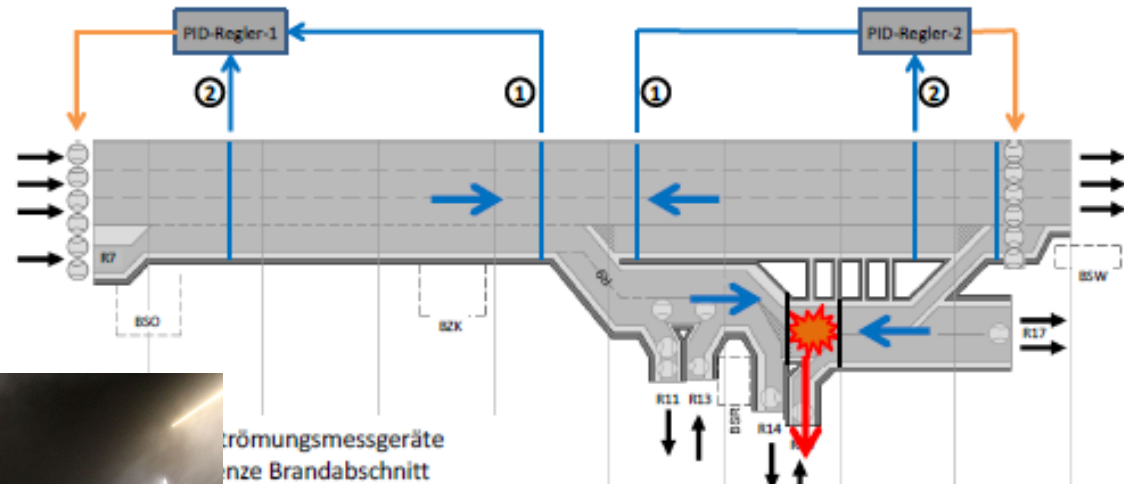


Different  
ventilation  
strategy for  
each zone





Fire zone  
W10



1-3 June 2022

4th International Tunnelling Forum, V

eter Sturm

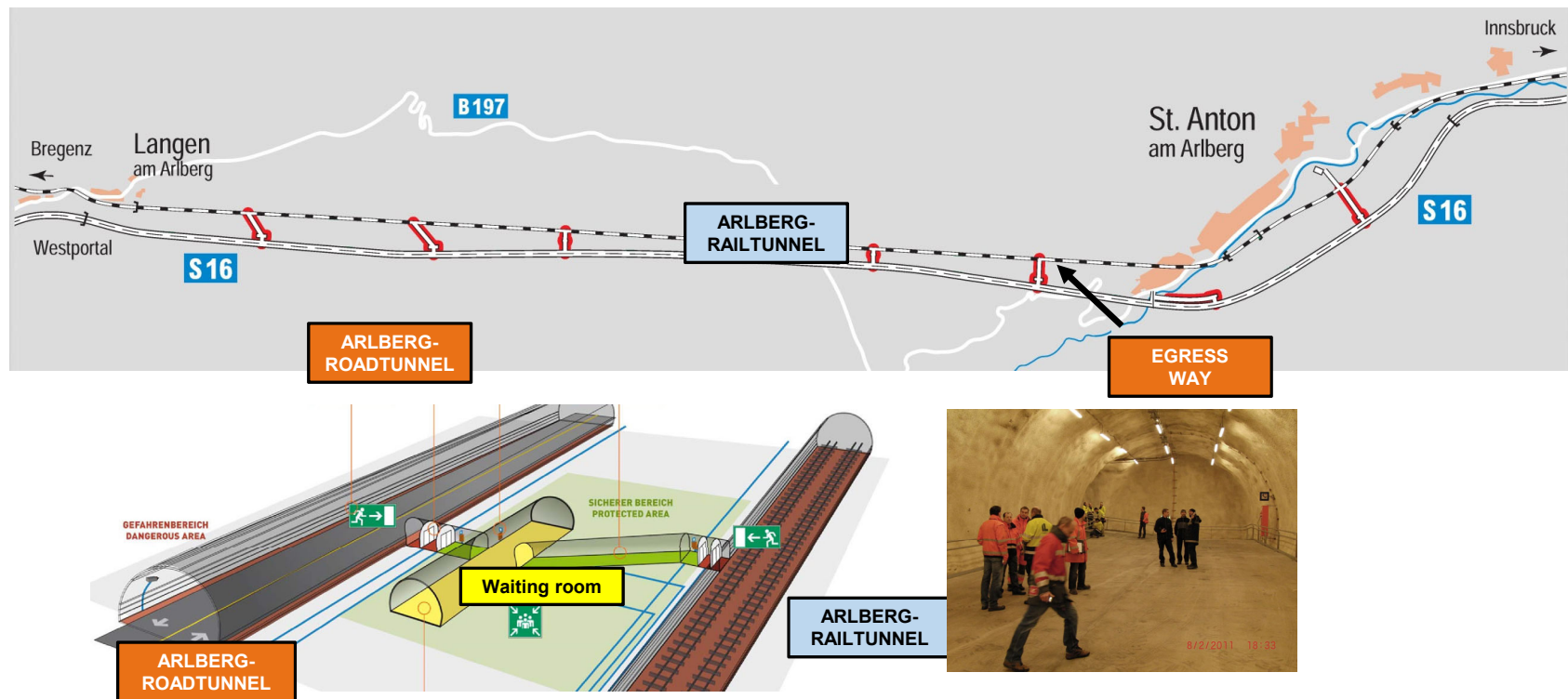
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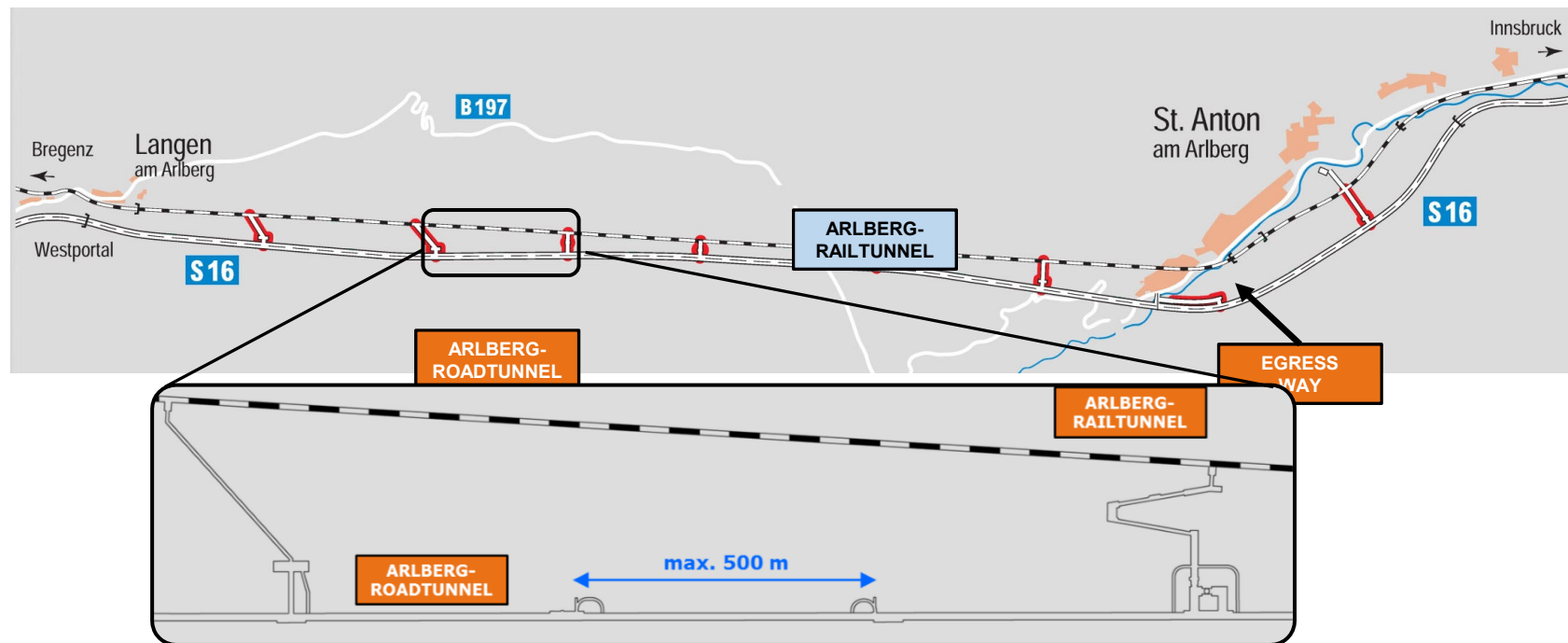
## Arlberg Tunnel (A)

- Length 15.5 km, single tube, bidirectional traffic
  - Only one winter safe W-E connection between Vorarlberg and Tyrol
  - Traffic: ~8'000 veh/d, 17% HGV
  - Full transverse ventilation system
  - In operation since 1978
  - Egress ways to the parallel running rail tunnel ~ every 1'700 m built in ~ 2000
  - Since 2015 full upgrade for ventilation and safety systems, egress ways every 500 m
- ➡ → Upgrading resulted in massive changes in the ventilation system and the safety/egress concept

## Before Upgrading

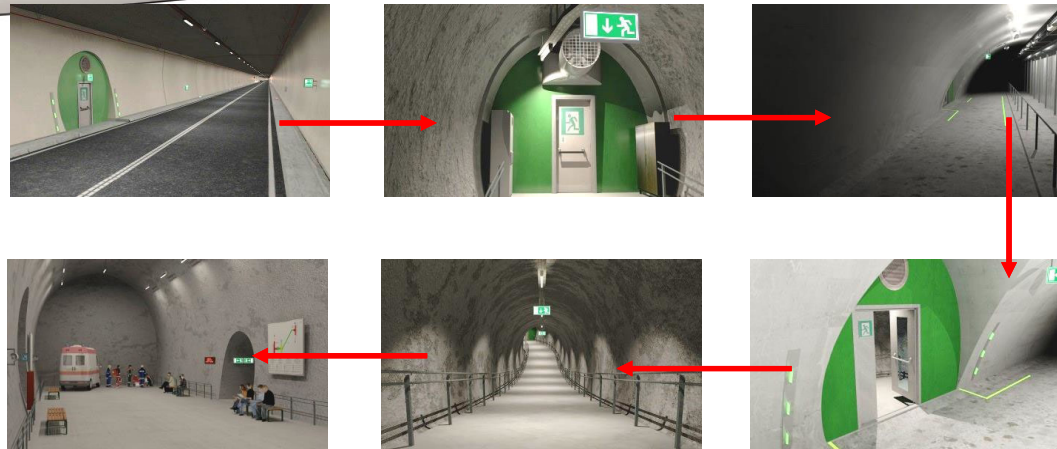


## Upgrading



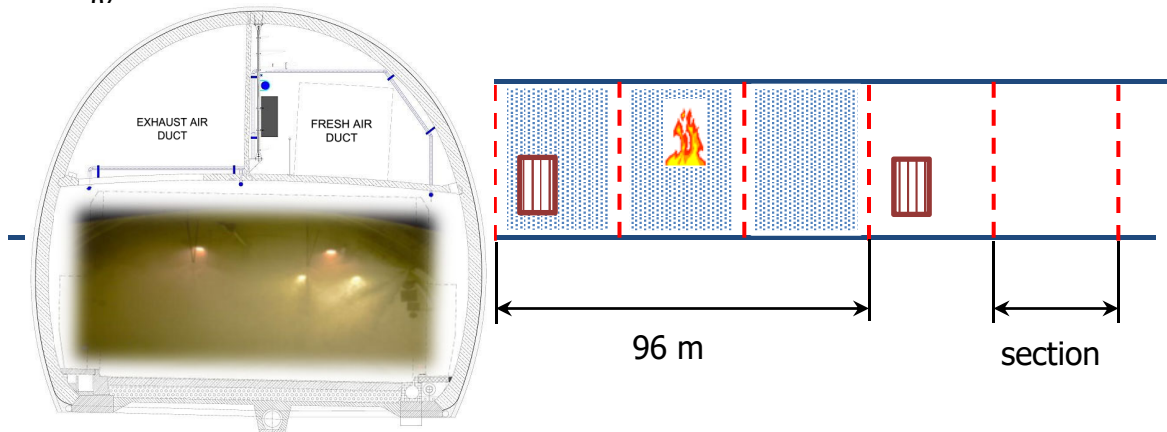


Upgrading:  
Egress from  
roadway into  
fresh air duct

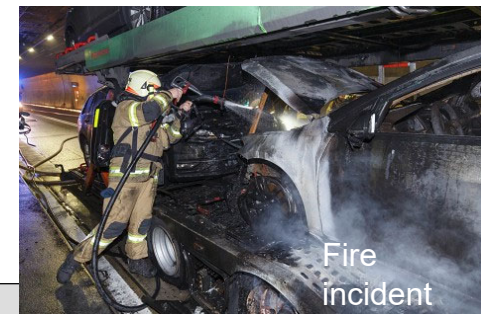


## Protection of the false ceiling with a high pressure water mist system

- ⊗ Liquid pool fire: 200 MW
- ⊗ Operation time: 120 minutes
- ⊗ Aqueous Film Forming Foam: 1 % - 3
- ⊗ Length of one section: ~32 m
- ⊗ Simultaneous section activation:
  - ⊗ regular cross section: 3
  - ⊗ including a break-down bay: 3 + 1

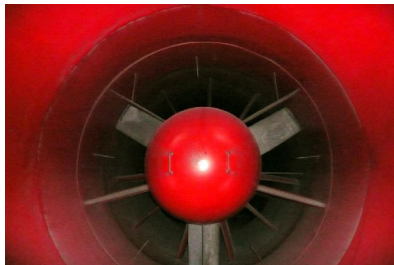
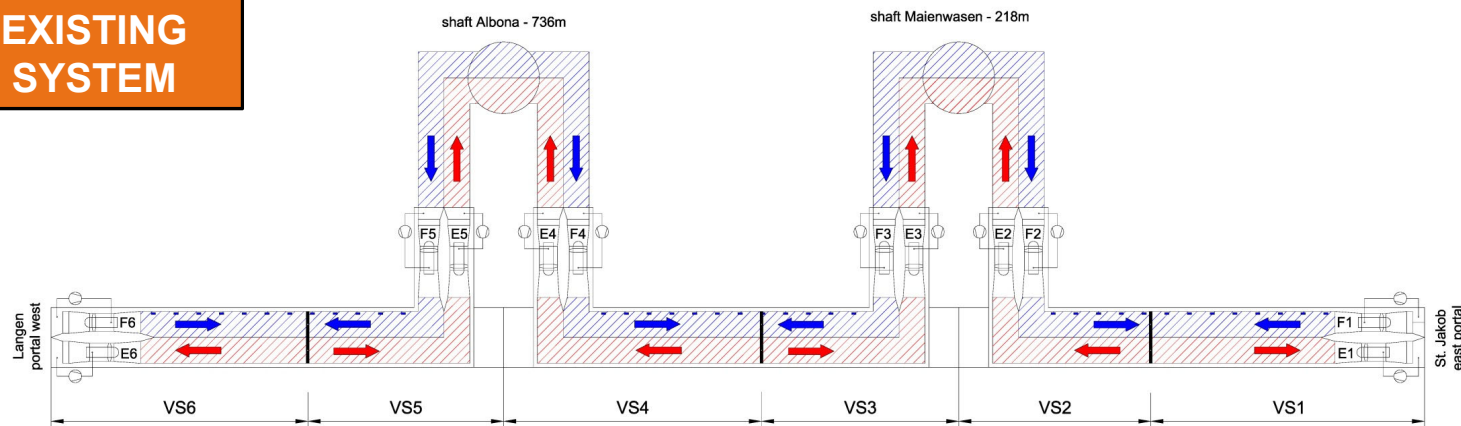


activation in the regular cross section



## Changes in the full transverse ventilation system

### EXISTING SYSTEM



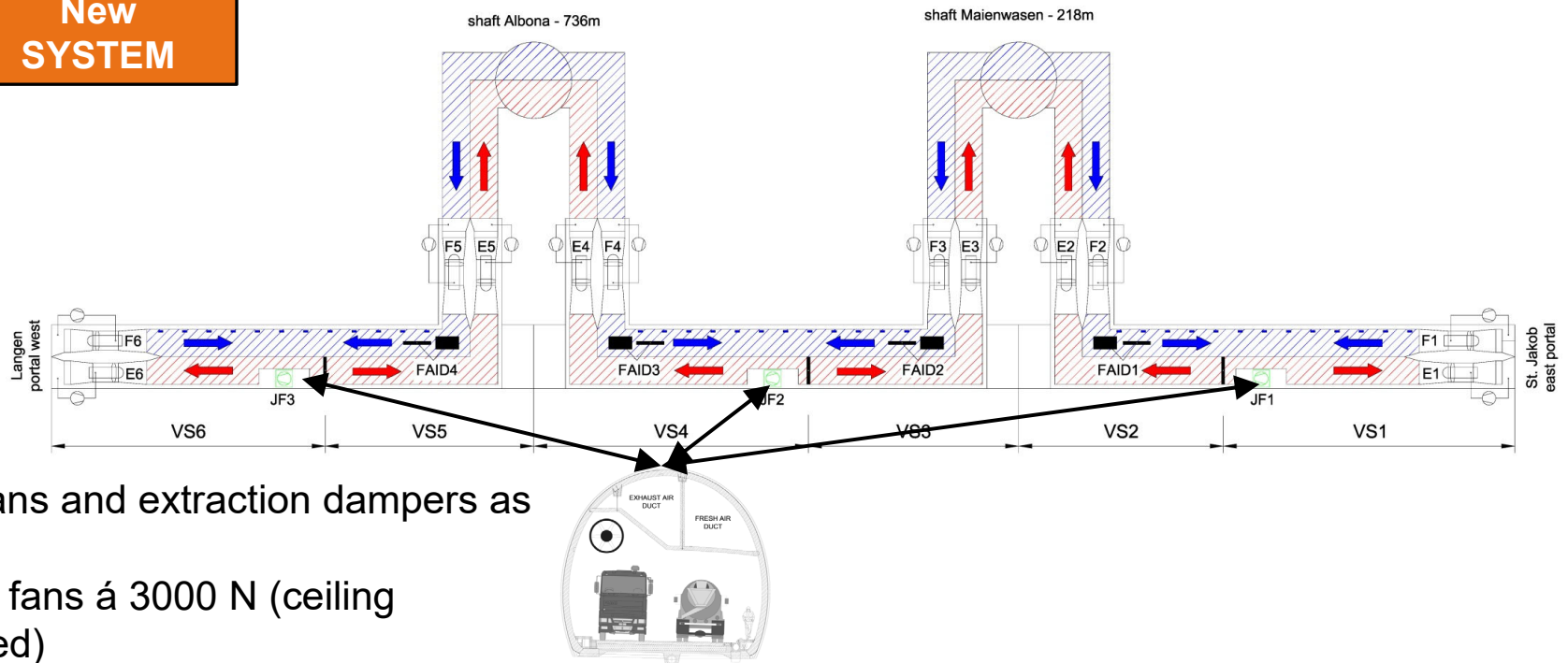
Axial fans: 6 supply and 6  
extraction fans á 300 m<sup>3</sup>/s,  
150 extraction dampers remotely  
controlled á 10 m<sup>2</sup>





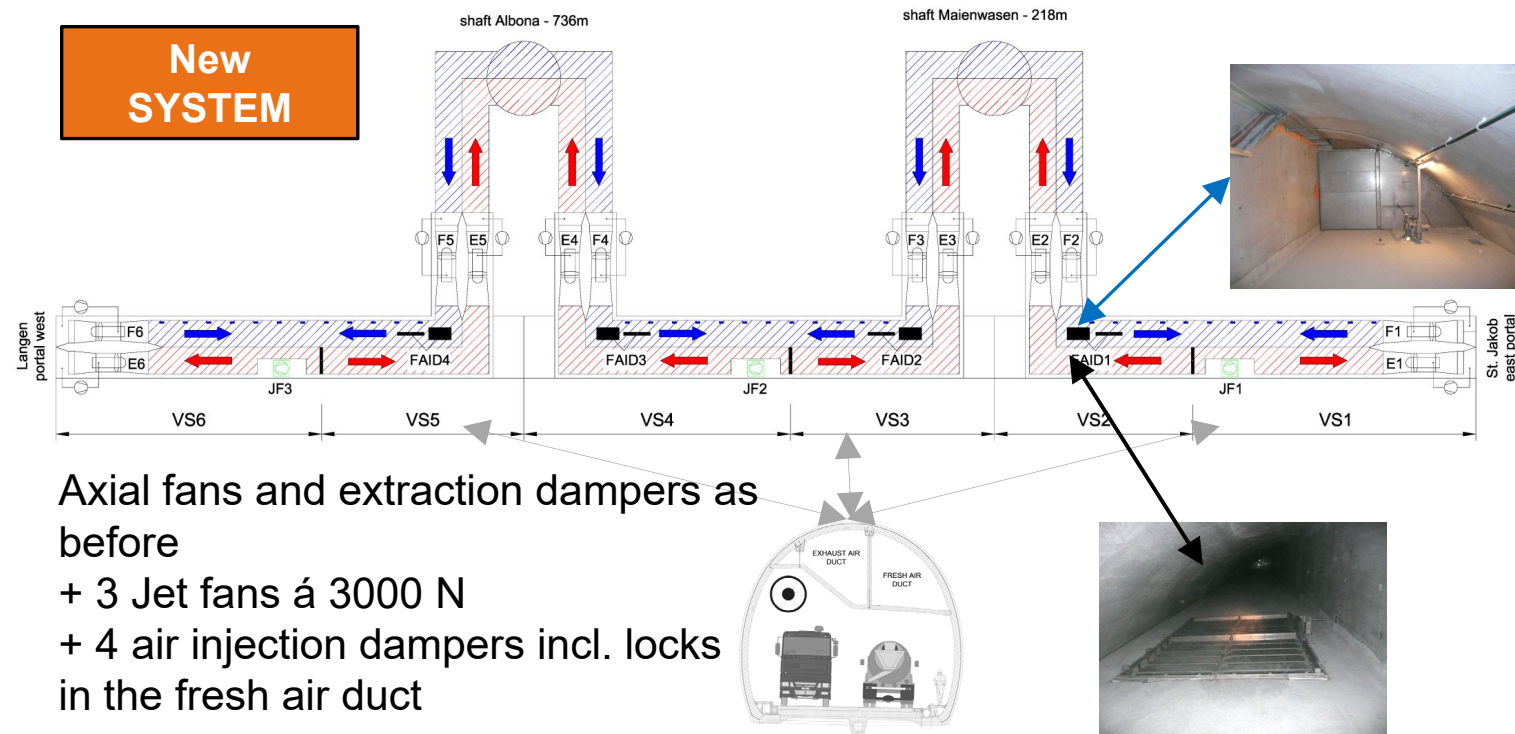
## Changes in the full transverse ventilation system

**New  
SYSTEM**



Axial fans and extraction dampers as before  
+ 3 Jet fans á 3000 N (ceiling mounted)

## Changes in the full transverse ventilation system



## Conclusions

- For standard tunnels design methods are straight forward and well defined.
- However, increased complexity and safety requirements need quite often a customized design which results in complex ventilation control strategies for fire cases.
- Intense testing of control systems is required before tunnel goes in operation.
- Complex control system needs a high quality standard of sensors and recurrent service and maintenance

Thank you for you attention

Arlberg tunnel  
VENTILATION SHAFT  
Albona, 736 m

