



Challenges for Ventilation Systems in Complex Tunnel Structures Examples from Urban and Mountainous Areas

Peter Sturm¹, Bacher Michael¹, Gregor Schmölzer², Johannes Rodler²

¹ Graz University of Technology, Austria

² FVT mbH, Graz, Austria

Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022



- 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.
- 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.



Retrofitting of existing systems is made considerably more difficult by the fact that current safety requirements have to be applied to existing structures.

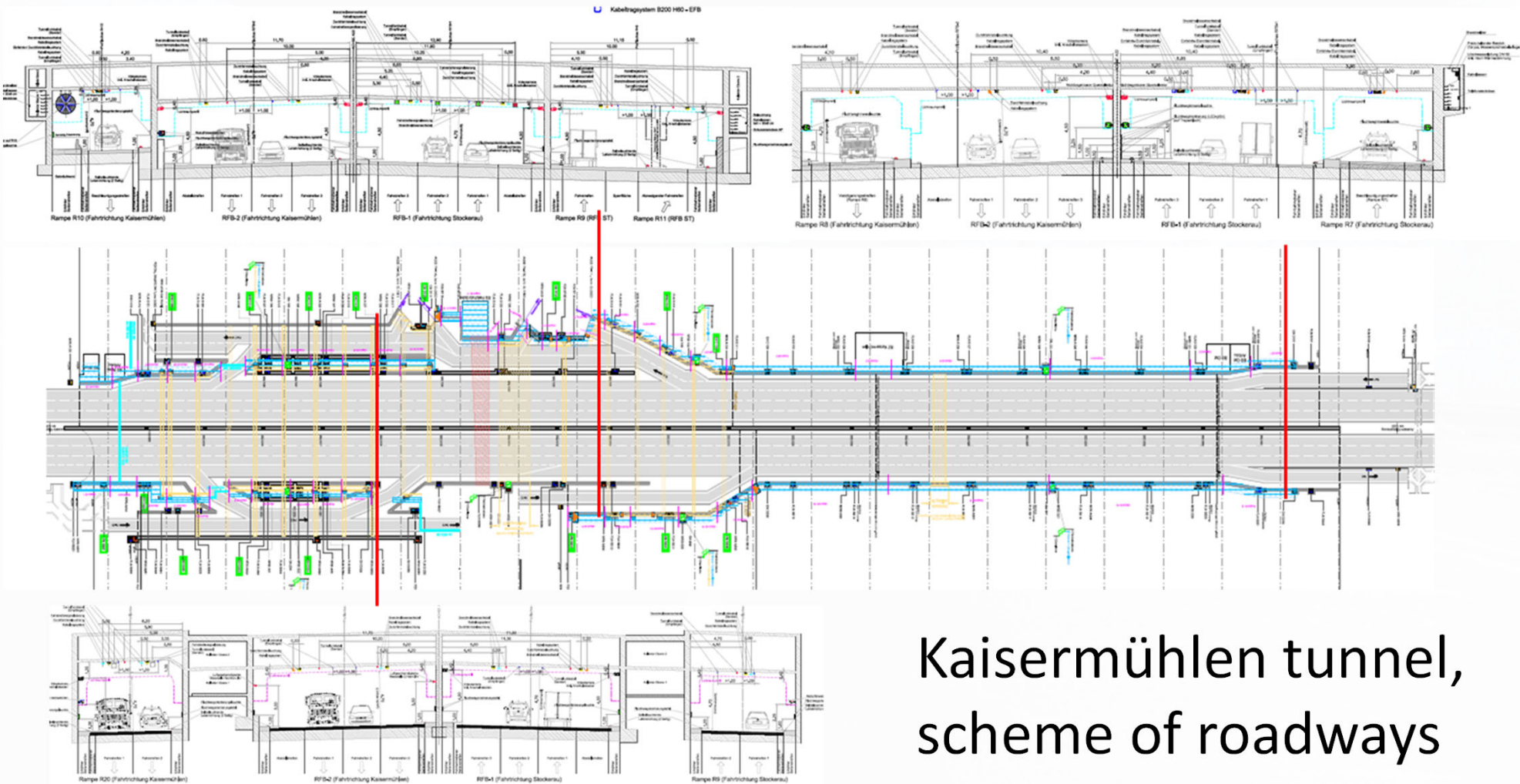
Two examples for upgrading road tunnels:

- 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 (direct connection to important oil infrastructure in the east of Vienna)
- Refurbishment done under operation



Kaisermühlen tunnel, scheme of roadways

Implementación de tecnologías en la operación de túneles

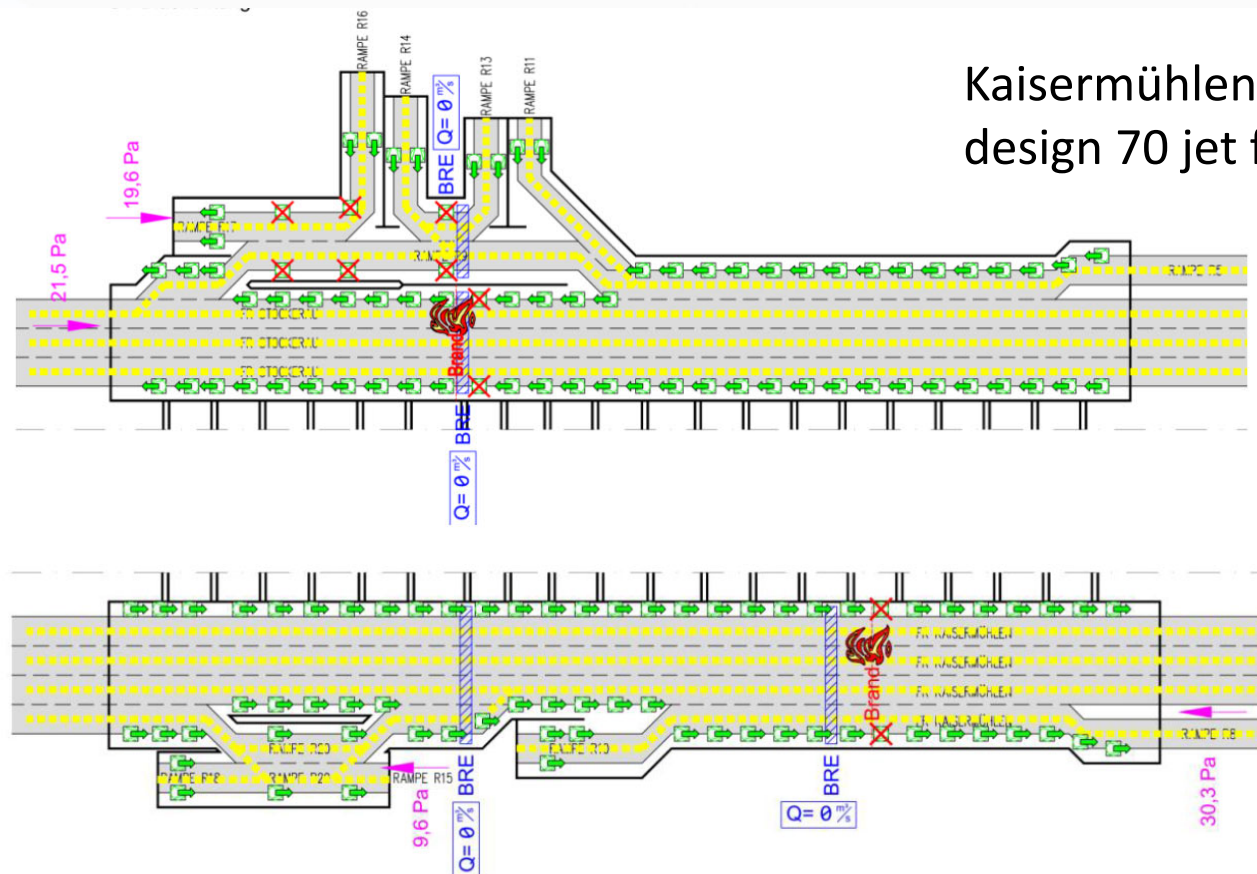
29 de marzo al 1 de abril de 2022



Portal

Implementación de tecnologías en la operación de túneles

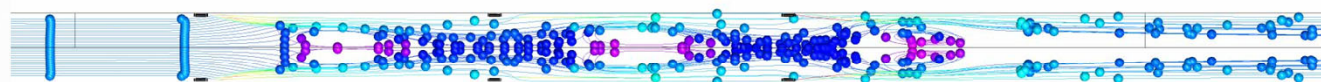
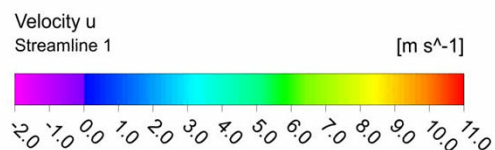
29 de marzo al 1 de abril de 2022



Kaisermühlen Tunnel – original design 70 jet fans á 300N

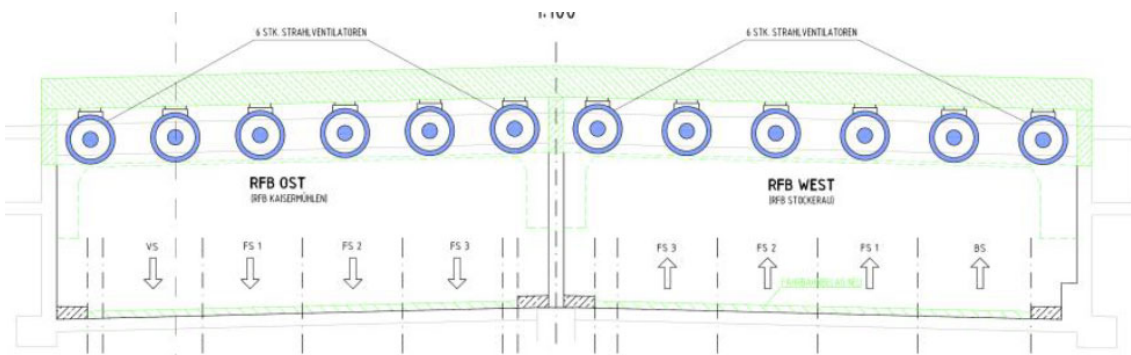


Kaisermühlen tunnel, old design - partial air recirculation



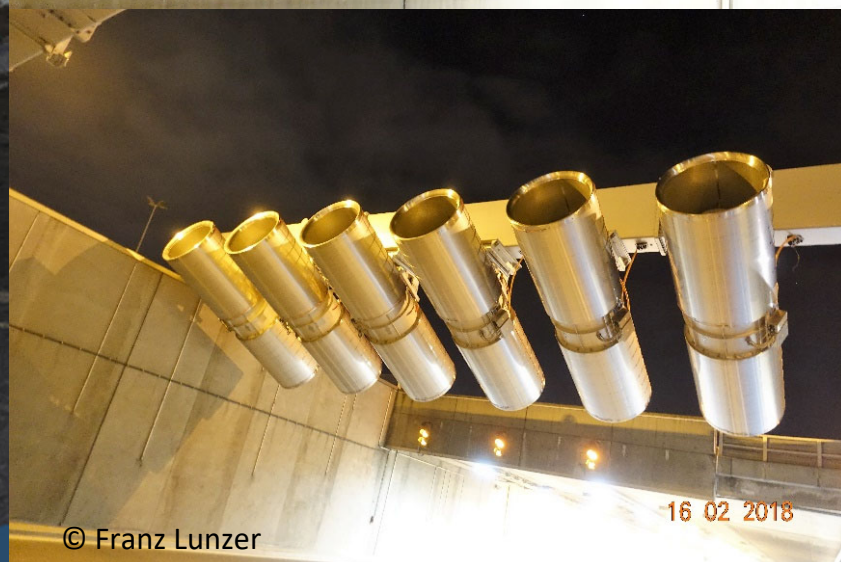


- Longitudinal ventilation with jet fans
- Existing tunnel (1990), quite small space for fans, 70 small fans (300 N) per tube
- Refurbishment: erection of niches for fans + portal installations
- Jet fans: thrust 2000 N, 1.6 m outer diameter, full reversible



Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022



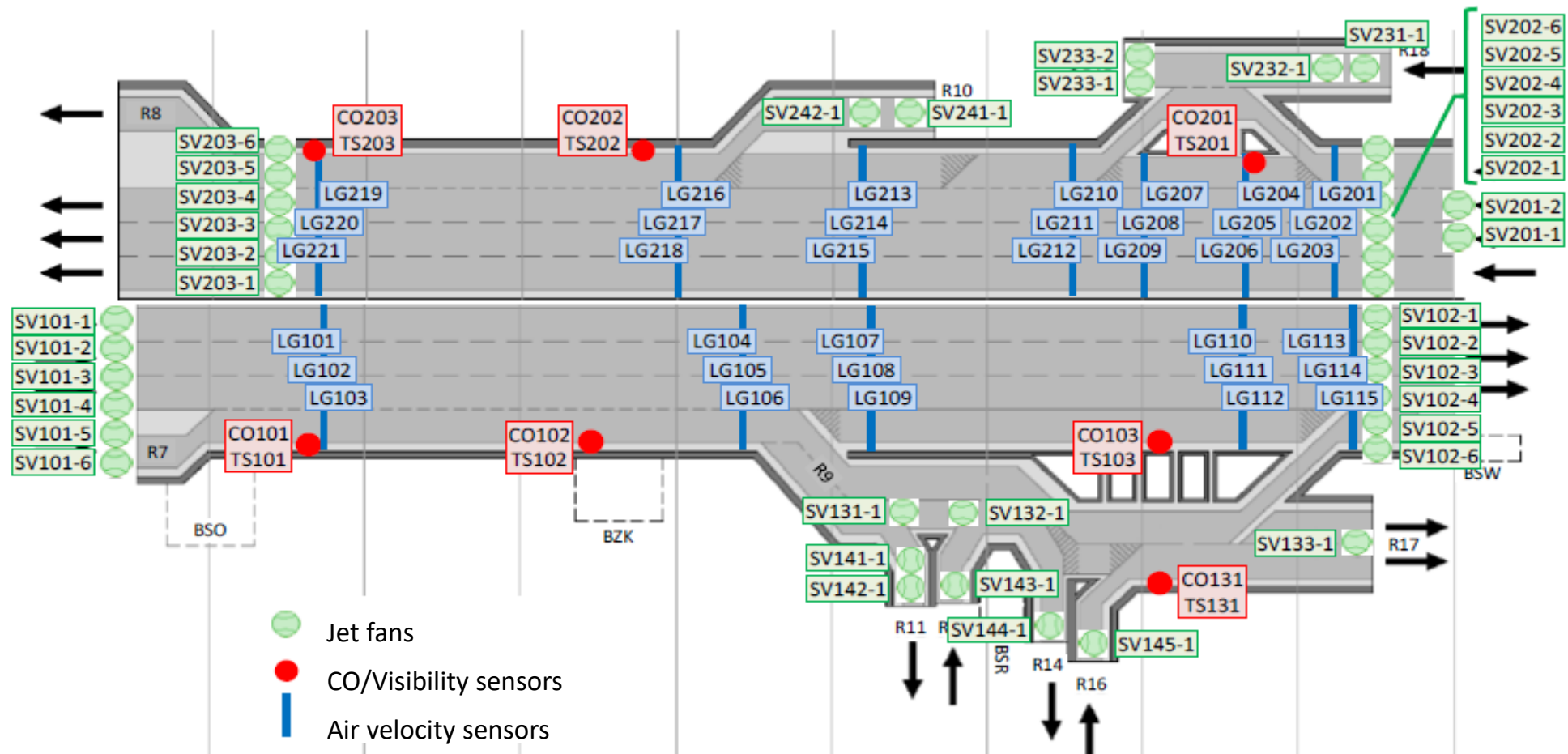
Kaisermühlen tunnel, new design

16 02 2018

© Franz Lunzer

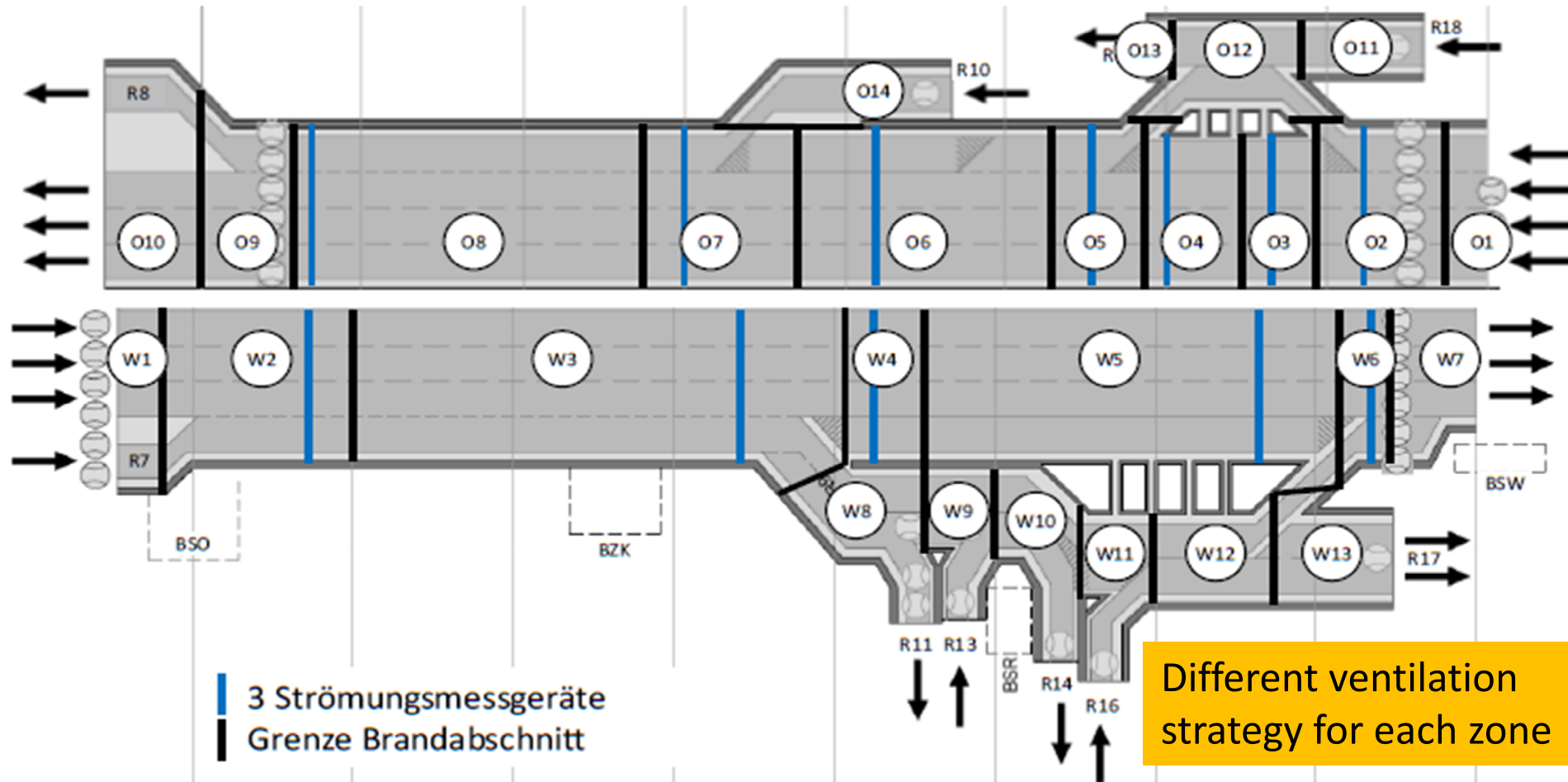
tecnologías en la operación de tuneles

29 de marzo al 1 de abril de 2022



Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022

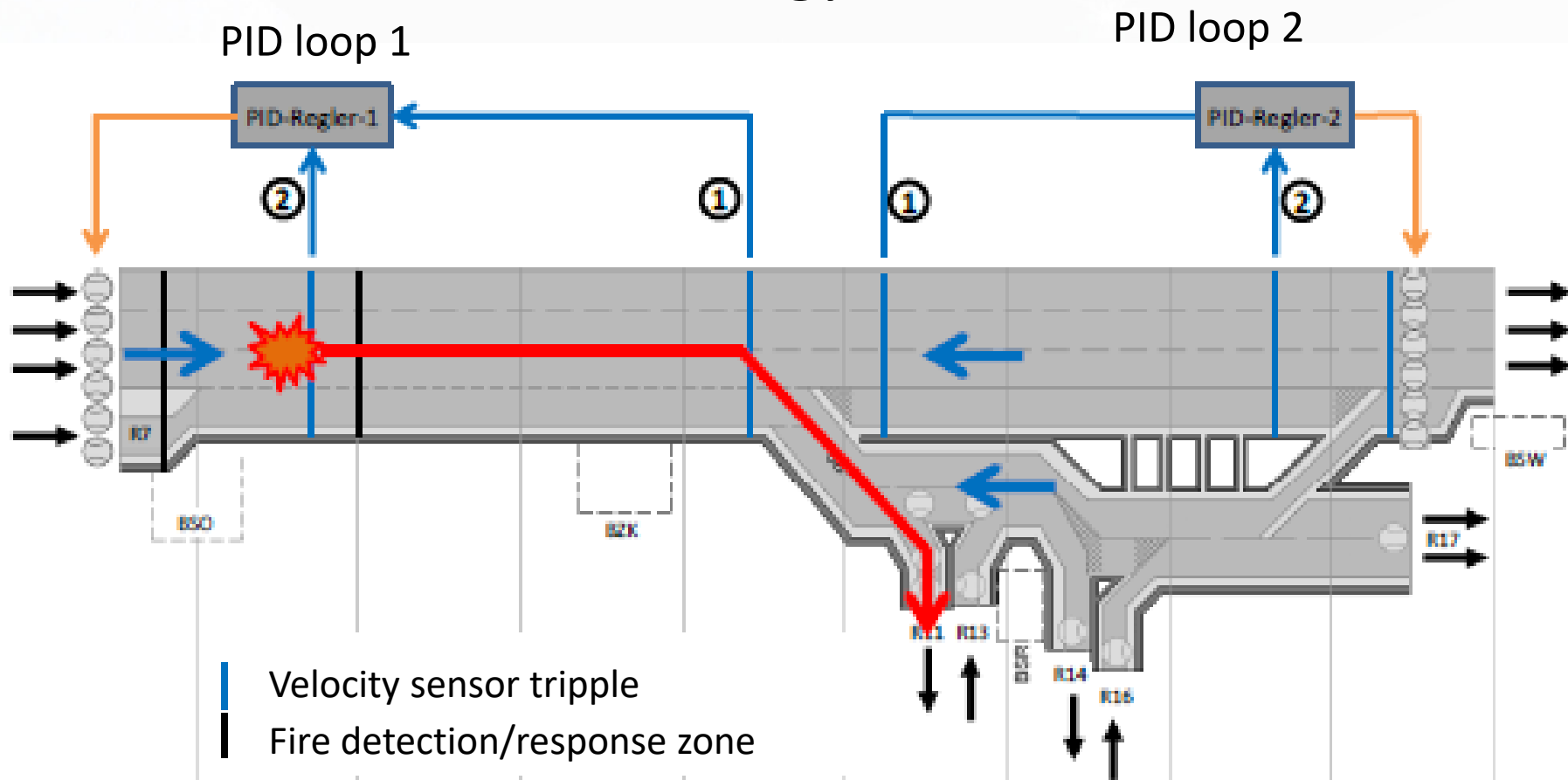


Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022

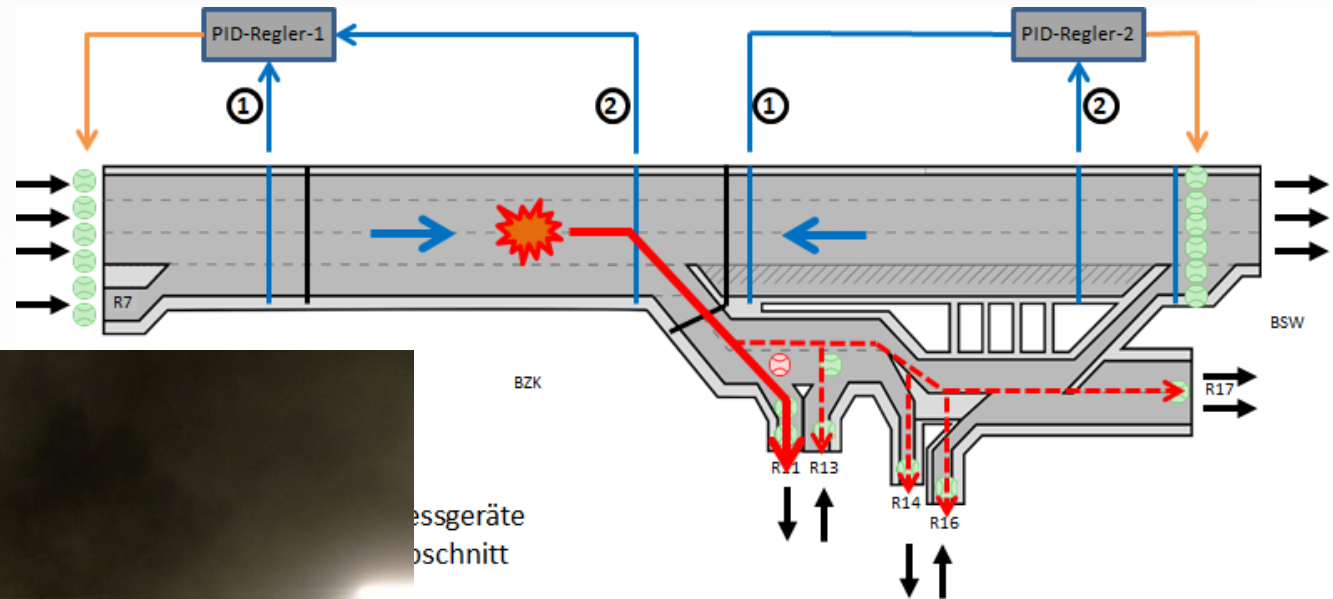


Control strategy – sector W2





Fire zone W3



—→ Fresh air
—→ Smoke

Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022

SEMINARIO MUNDIAL DE TÚNELES CARRETEROS



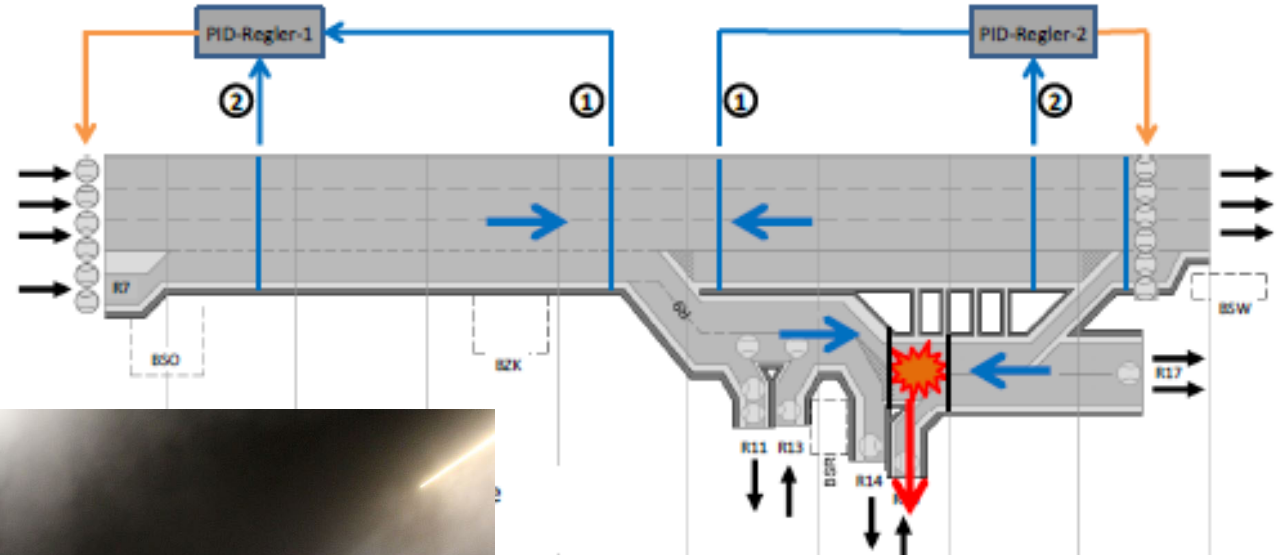
La movilidad es de todos

Mintransporte



Fire zone W10

- Fresh air
- Smoke





- Complex tunnels/tunnel networks are common means for managing traffic in urban areas
- Connected aerodynamics require closed loop ventilation control [PI(D)] in fire case
- Speed controlled jet fans are necessary
- In depth on-site testing is necessary to define the parameters for the control scheme
- Testing requires time
- Complex control system needs a high quality standard of sensors and recurrent service and maintenance

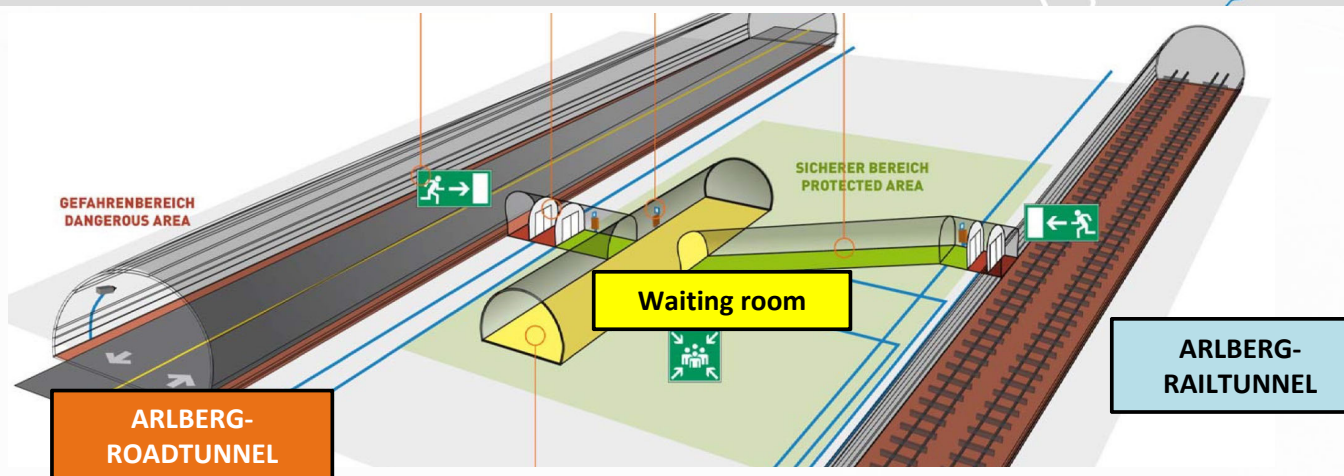
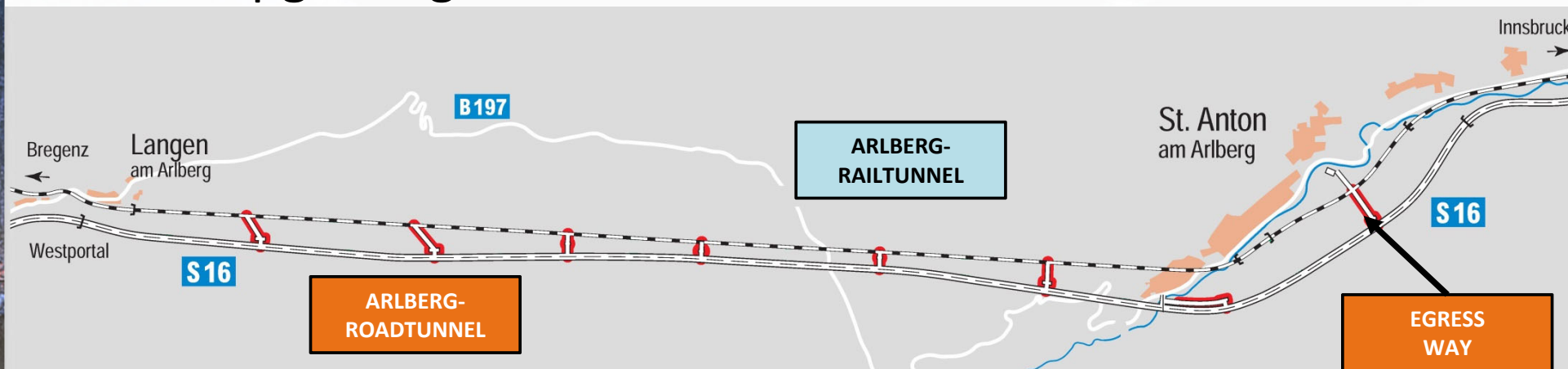


Arlberg Tunnel (A)

- Length 15.5 km, single tube, bidirectional traffic
 - 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

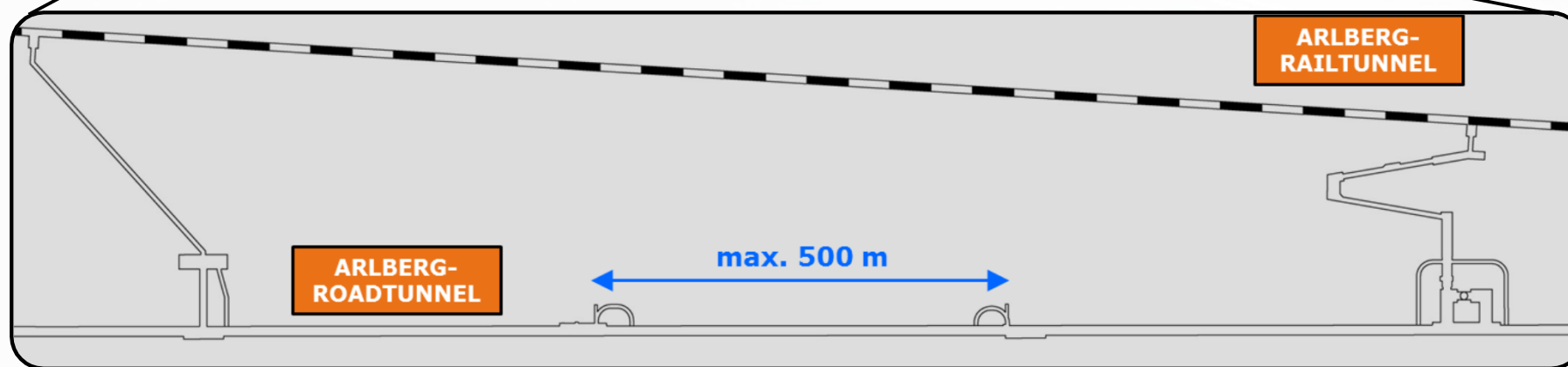
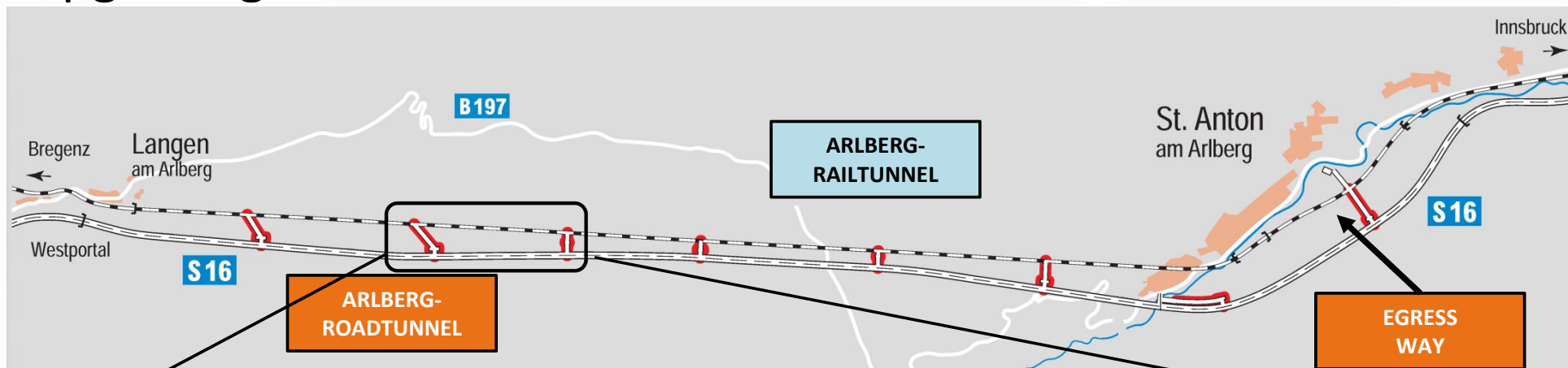


Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022



Upgrading

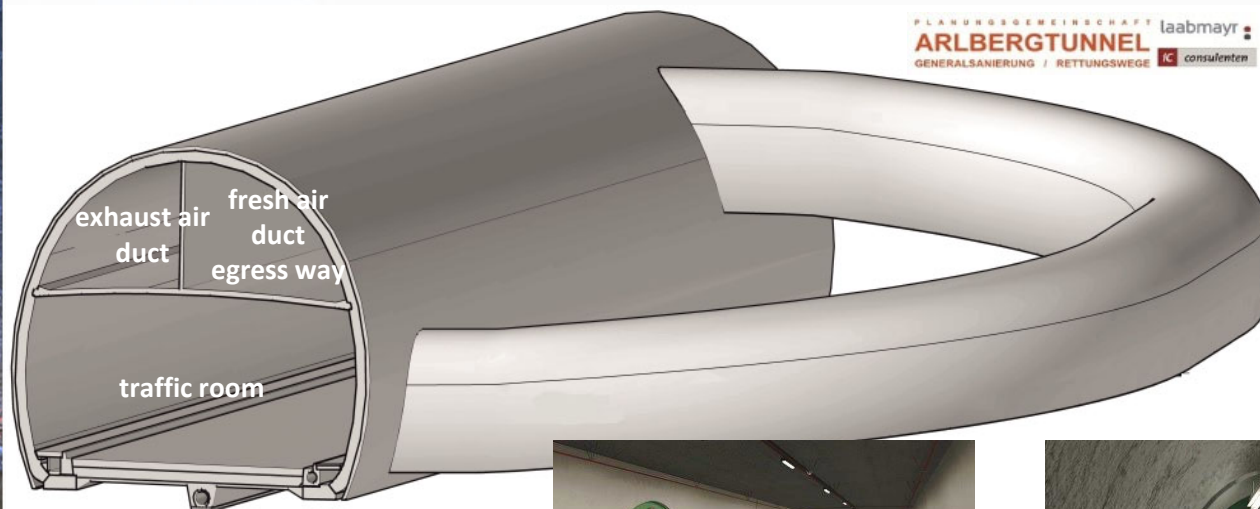


Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022



PLANUNGSGEMEINSCHAFT laabmayr
ARLBERGTUNNEL
GENERSANIERUNG / RETTUNGSWEGE ic consulenten



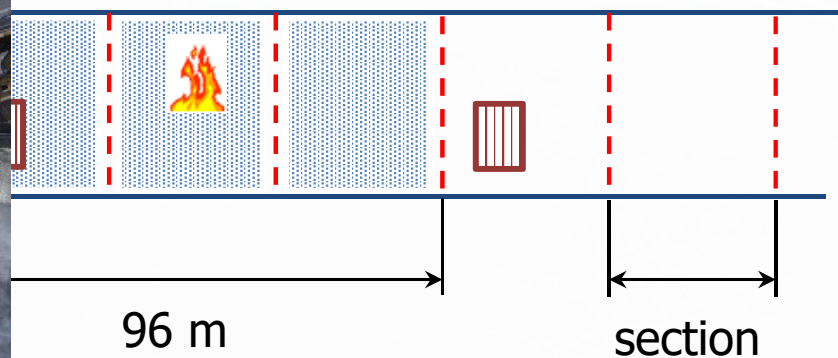
Upgrading: Egress from roadway into fresh air duct





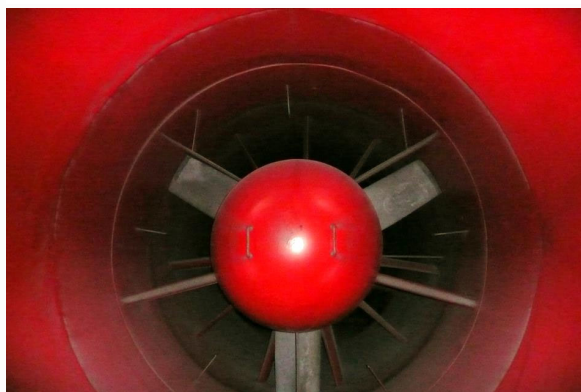
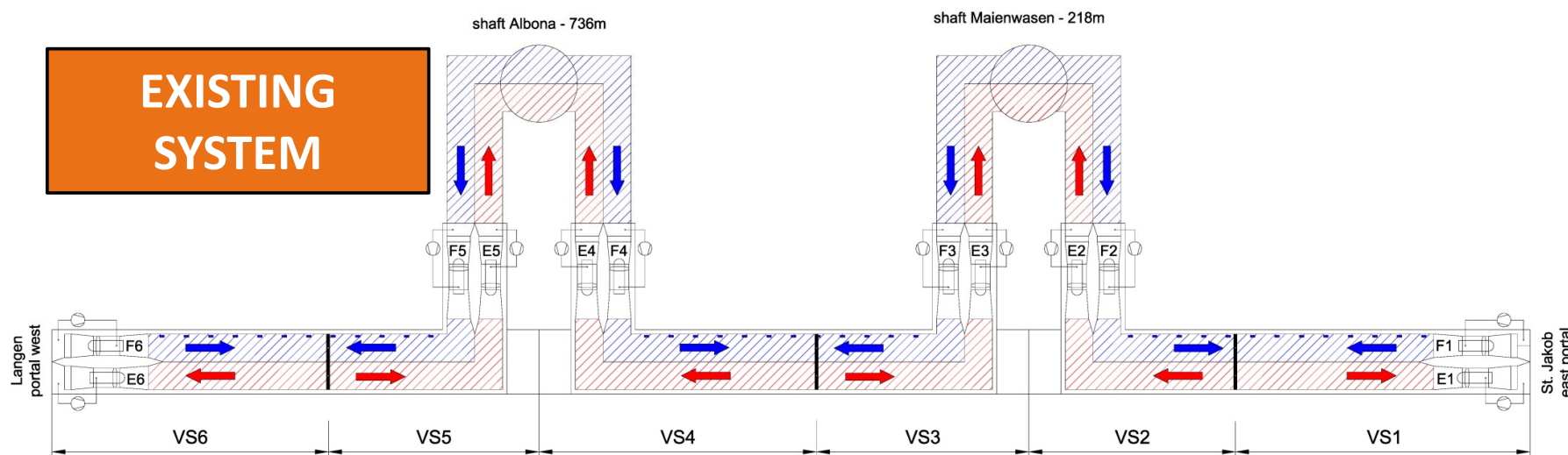
Protection of the false ceiling with a high pressure water mist system

- ⊗ 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

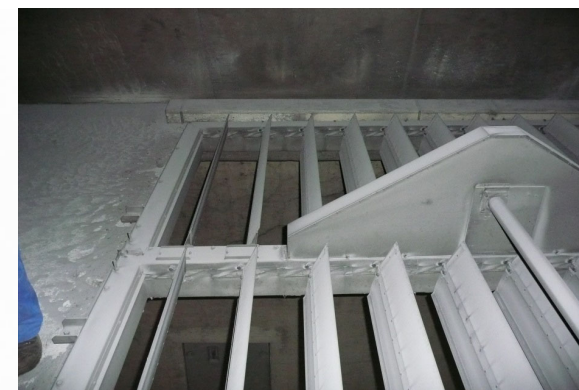


activation in the regular cross section

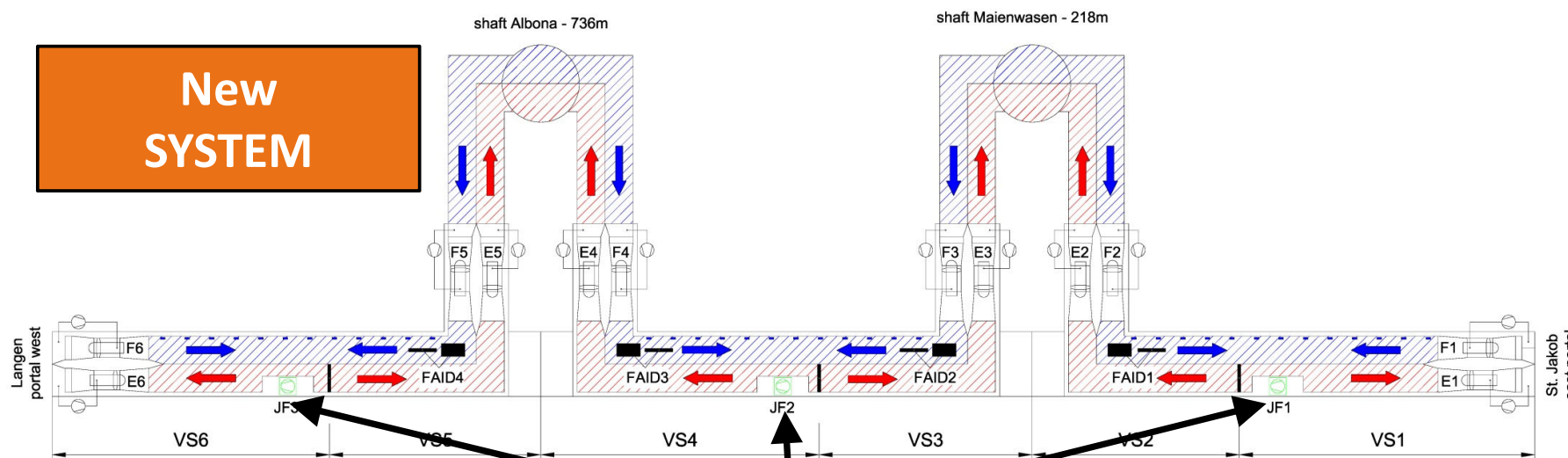
Changes in the full transverse ventilation system



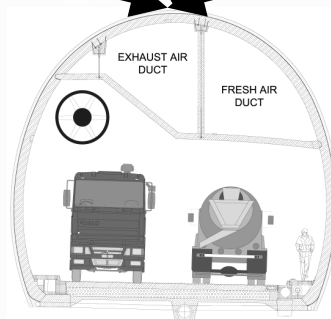
Axial fans: 6 supply and 6 extraction fans á 300 m³/s
150 extraction dampers
remotely controlled á 10 m²



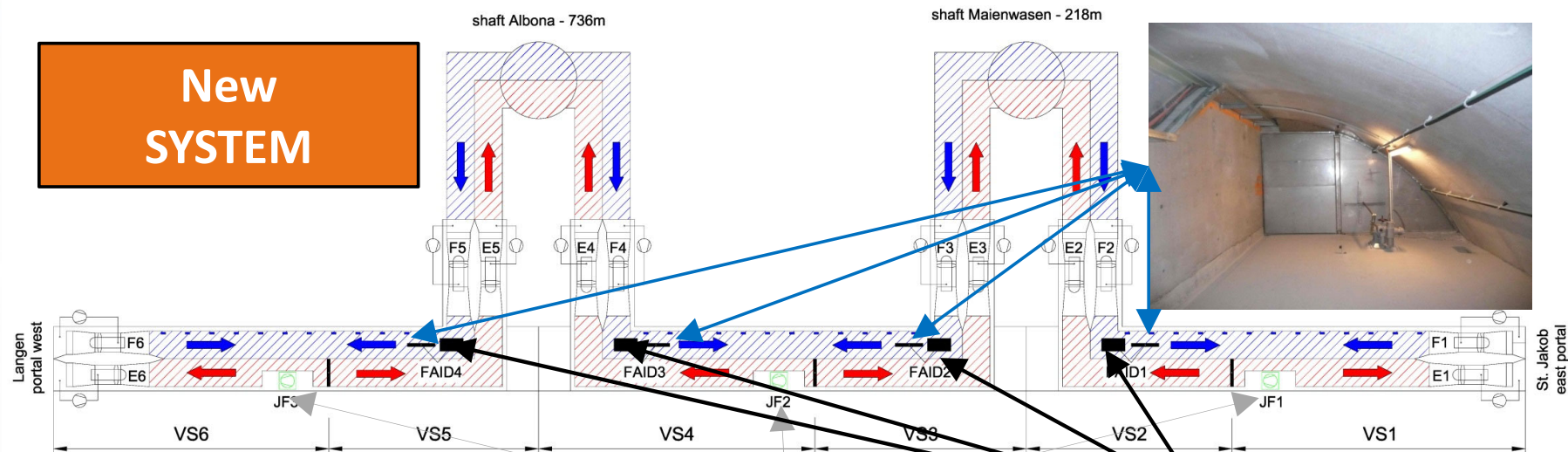
Changes in the full transverse ventilation system



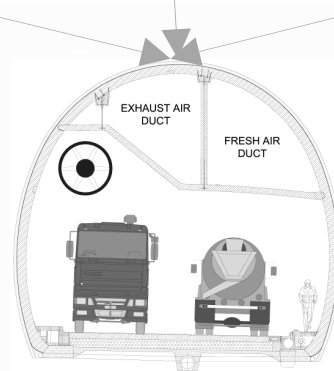
Axial fans and extraction dampers as before
+ 3 Jet fans á 3000 N (ceiling mounted)



Changes in the full transverse ventilation system



Axial fans and extraction dampers as before
+ 3 Jet fans á 3000 N
+ 4 air injection dampers incl. locks in the fresh air duct





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.
- Recurrent system tests are required to provide a reliable and safe system.



Thank you for you attention
Gracias por su atención

Arlberg tunnel
VENTILATION SHAFT
Albona, 736 m



Implementación de tecnologías en la operación de túneles

29 de marzo al 1 de abril de 2022