

▶ **Tested safety** ▶▶

TROX tunnel dampers for underground transport systems



TROX[®] TECHNIK
The art of handling air

The International Center
Fire Protection (ICB) in
Neukirchen-Vluyn,
Germany, opened in 2009



► The art of handling air ►►

TROX understands the art of handling air like no other company.

Since its foundation in 1951, TROX has been developing and manufacturing sophisticated components, units and systems for ventilation and air conditioning as well as for fire and smoke protection. Dedicated research and development have made TROX a global leader of innovation in these fields.

The company's competence in fire and smoke protection technology is unique in the sector. For decades, TROX has been developing components and systems for fire and smoke protection in buildings and underground transport systems. TROX offers its customers tested safety, the highest quality standards, and other numerous advantages.

The International Center Fire Protection (Internationales Center Brandschutztechnik = ICB) is the testing, research, and development centre of the TROX GROUP. In one of the most state-of-the-art laboratories for fire protection technology in Europe, newly developed products are tested under practical conditions according to national and international standards or building-specific requirements. The core of ICB is a unique combination furnace for wall and ceiling tests. The size of the furnace permits fire tests on large-scale tunnel dampers, amongst other things.

TROX is a certified company and active member in the Research Association for Underground Transportation Facilities (Studiengesellschaft für unterirdische Verkehrsanlagen e. V. = STUVA). STUVA is involved in independent, basic research and publication of scientific knowledge in regard to safety in underground transport systems.



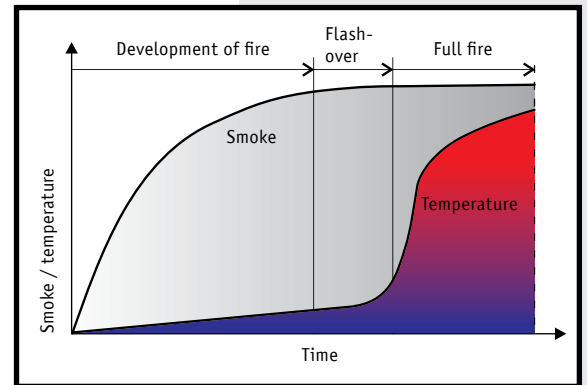
► When safety has top priority ►►

In comparison with open spaces and buildings, the escape possibilities in underground transport systems are very limited. If safety standards are not observed, a fire can have catastrophic consequences.

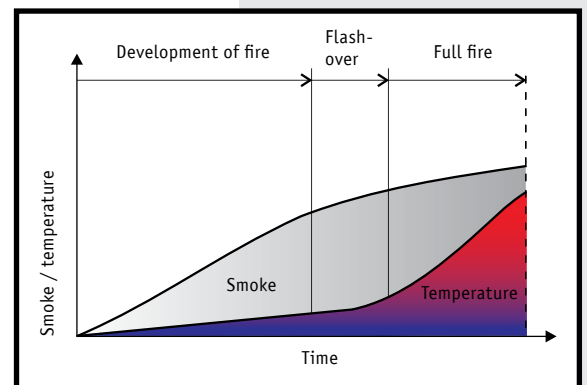
The development of smoke in the case of a vehicle fire is relatively harmless outdoors. In a tunnel, however, it can have deadly consequences. The spreading speed of poisonous fire gases within the tunnel far exceeds the human speed of escape.

Most people who have died in fires in underground transport systems were usually victims of smoke inhalation.

A burning car generates fire loads of up to 5 MW, a lorry even over 100 MW. Fire loads such as these have destructive effects on the supporting structure of the tunnel and lead to damage costs in millions.



Tunnel without smoke extract



Tunnel with smoke extract

In the case of a fire in a tunnel without a smoke extract system, the vehicle passengers have five minutes at the most to save themselves; after that, the level of smoke development is too high. The period of time available for self-rescue must thus be extended by suitable smoke extract systems that keep the tunnel free of smoke. In addition to helping people save their own lives, smoke extract systems also aid in fire fighting. A fast, targeted extinguishing of the fire is possible if the development of smoke does not become a major obstruction in the attempt to extinguish the fire.



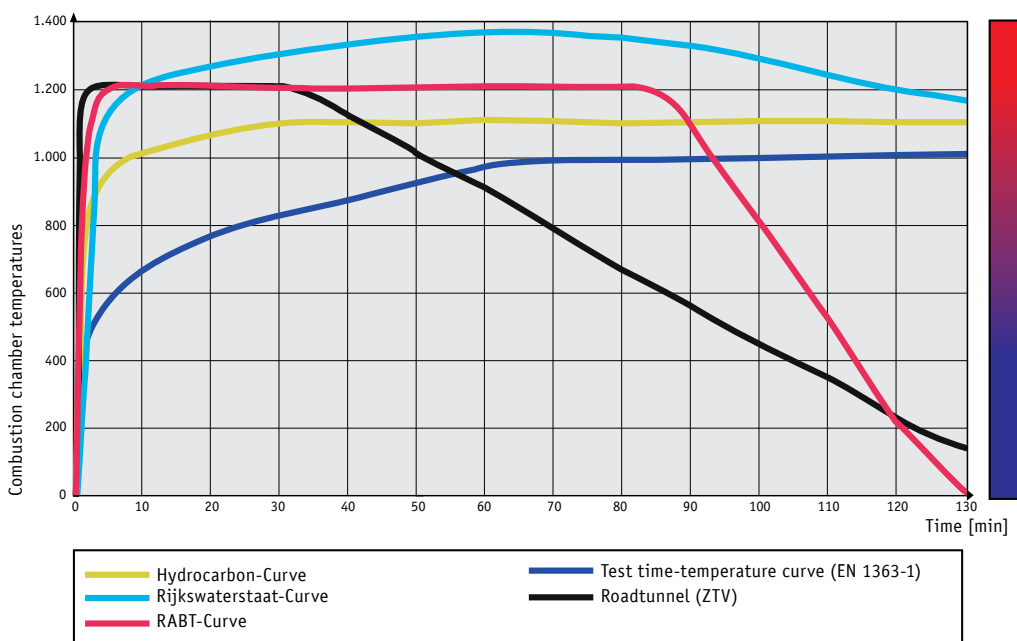
According to the Guideline for the Equipping and Operation of Roadway Tunnels

(Richtlinie für die Ausstattung und den Betrieb von Straßentunneln = RABT) and European Directive 2004/54/EC tunnels must have smoke extract dampers at a regular distance from each other; these dampers must function reliably at a temperature of 400 °C for up to two hours.

Beyond tested safety, the customers of TROX place further demands on tunnel dampers. Accordingly, tunnel dampers should be low-maintenance, have a long life expectancy, and are highly corrosion-resistant. In addition, fast, problem-free installation is a great advantage, especially in the case of tunnels that are already in use, because faster retrofitting reduces traffic jams and costs. Since €7 billion is earmarked for investment in the renovation of road tunnels by 2019, this will stimulate growth of projects in this area.



Time-temperature curves for fire testing procedure



Extreme operational conditions

In normal operation

- Large temperature and humidity fluctuations
- Pressure waves and vibrations created by vehicles
- High degree of dust and soiling

In case of fire

- Hot fire gases
- High temperatures
- Extinguishing water and steam

► Tested quality ►►

TROX leaves nothing to chance. To prove the functional reliability of TROX tunnel dampers under realistic conditions, they are subjected to extensive internal and external loading tests. Test reports from national and international testing institutes document the high level of safety. TROX thus fulfils the highest standards worldwide.

With a certified production process, TROX guarantees production quality without compromise all over the world. TROX tunnel dampers are manufactured in Germany and Malaysia. From the goods inwards inspection to delivery of the final product, all processes are subject to thorough quality control. The results of the relevant tests are documented and provided to the customers upon request.

The TROX quality management system is certified on the basis of DIN EN ISO 9001. The manufacturing process of smoke extract dampers Types JF-S and JF-P is quality-controlled at all levels. For the base materials supplied, for example, like stainless steel 1.4571 (V4A quality), TROX has the corresponding material certificates.

TROX's manufacturing employees are qualified according to DIN EN 287-1. External service providers in the manufacturing process are certified according to all aspects of ISO 9001. During production, quality tests, such as the leakage test, are constantly performed on test rigs according to DIN EN 1751.



If you add up the lengths of all tunnels in Germany, you will get a total length of 1,320 km.

*640 km of underground/urban railway tunnels
480 km of long-distance railway tunnels
200 km of road tunnels*

In Germany, this corresponds to a distance of a trip from Kiel to Munich and back. At present, 51 tunnels are under construction. In the next 10 years, an additional 515 km are planned.

Europe has a total of approximately 15,000 km of traffic tunnels. This corresponds to the distance from Lisbon to Moscow and back. Spain and Italy have the most tunnels.

*15,000 km in Europe
22,500 km in Asia
100 km in Australia
650 km in South America
650 km in North America*

The total length of tunnels worldwide amounts to 38,900 km. This is about 93 % of the circumference of the earth.

► Tailored solutions ►►

Underground transport systems are generally unique. Standardised solutions in this area hardly exist, not even for tunnel dampers. To recognise and realise potential optimisation, TROX engineers and product managers are available to support their customers in the design phase. This results in project specific solutions that meet all technical and economic requirements.



The individual project planning includes exemplary, project-specific service that not only guarantees a permanently high safety standard, but also lowers operating costs and minimises downtimes.

The efficiency of TROX tunnel dampers can be seen in both installation and operation. Depending on the requirements, various steel qualities up to V4A (1.4571) can be used. These offer the highest degree of corrosion resistance and are characterised by a long service life and low maintenance.

TROX engineers have optimised the design with a special focus on fast, safe installation. Thanks to the use of a special subframe, for example, the installation of a tunnel damper has been reduced to only 30 minutes. In sum, this leads to a considerable acceleration of the construction work in the case of longer tunnels.

The large-scale manufacturing capacities of TROX and sophisticated logistics guarantee the timely delivery of all products all over the world.

► Uncompromising safety ►►

TROX tunnel dampers are available as a complete solution including the drive motor, thermal insulation enclosure, and, if required, subframe. This guarantees a maximum functional reliability of combined elements.

Greater efficiency

Since only the tunnel dampers in the direct vicinity of the fire area are opened, the other dampers must remain closed, sealed as air-tightly as possible to increase the efficiency of the smoke extract system and protect the tunnel sections not affected by the fire from poisonous fire gases.

On TROX tunnel dampers, spring-loaded seals allow for the longitudinal expansion of the components at temperatures of up to 400°C for more than 120 minutes and guarantee high levels of air-tightness, even at high pressures. Depending on requirements, the damper can have either parallel or opposed blade action. Due to the aerodynamic profile of the blades, the pressure loss across the damper is low.

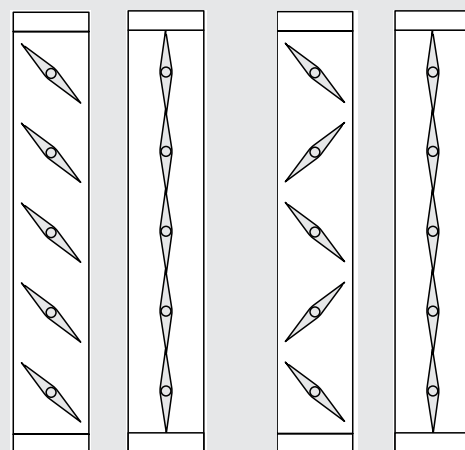
Extreme temperature resistance

Thermal insulation enclosures and aerodynamically designed cover plates protect the electric actuators of the tunnel dampers from high temperatures in case of a fire and guarantee functional reliability.

Our latest achievement has been the successful fire test in accordance with the French Ministerial Directive 2000-63.

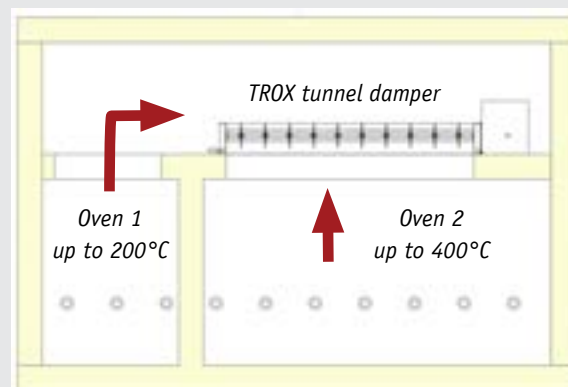
Safe function tests

The tunnel dampers have position limit switches so that their functionality can be tested remotely in a central control room at any time. Via TROXNETCOM, the actuators can also be integrated into the direct digital control (DDC) system.



JF-P parallel

JF-S opposed



Fire test according to FN 2000-63



Variable design

- Parallel or opposed blades
- Stainless steel frame elements, blades, and external rods (1.4571), alternatively galvanised or powder-coated
- Stainless steel bearings
- Stainless steel seals
- Electric actuators, optionally with thermal insulation enclosure
- Integration into the direct digital control system with TROXNETCOM
- Fire resistance up to 400 °C for 120 minutes

The illustration shows you how an underground system can be equipped with innovative TROX products and systems



► TROX solutions for safe train and metro tunnels ►►

TROX tunnel dampers are used for the ventilation and smoke extract of underground transport systems. In the event of a fire the smoke is controlled to provide tenable conditions for the rescue of passengers. Tunnel dampers are also used for pressure relief, as a protection from the pressure surge caused by approaching trains.

TROX tunnel dampers are rated for high temperature smoke extract up to 400 °C for 120 minutes. In special requirements, dampers have also been tested to provide fire integrity in accordance with BS 476 , part 20, for four hours at temperatures up to 1000 °C.

- 1** Smoke exhaust axial fans
- 2** Fan shut-off dampers
- 3** Sound attenuators
- 4** External weather louvres
- 5** Smoke extract / isolation dampers

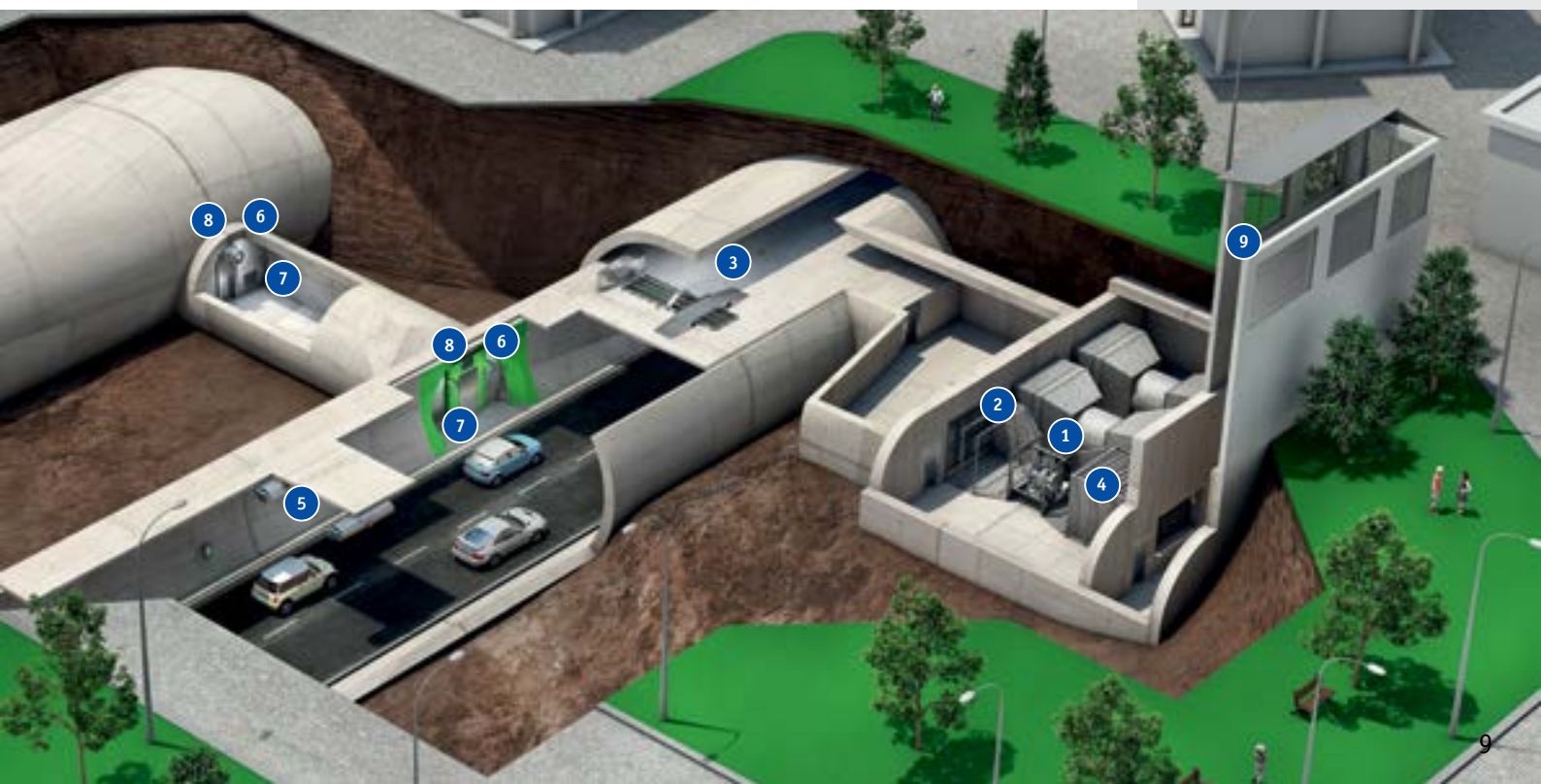
► TROX solutions for safe road tunnels ►►

Tunnel dampers in road tunnels are part of the ventilation and smoke extract system. They are installed as shut-off dampers in ceilings or walls, or as fan shut-off dampers. If triggered, they open or close depending on the requirement.

A system of X-FANS, fire dampers and pressure relief dampers helps to keep escape routes and refuge areas safe.

- 1 Smoke exhaust axial fans
- 2 Fan shut-off dampers
- 3 Smoke extract dampers with heat-insulated, encased actuator and bridge
- 4 Sound attenuators
- 5 Jet ventilation systems
- 6 Tunnel fire dampers
- 7 Pressure relief dampers
- 8 X-FANS axial fans
- 9 External weather louvres

The illustration shows you how a road tunnel can be equipped with innovative TROX products and systems





► Challenges mastered ►►

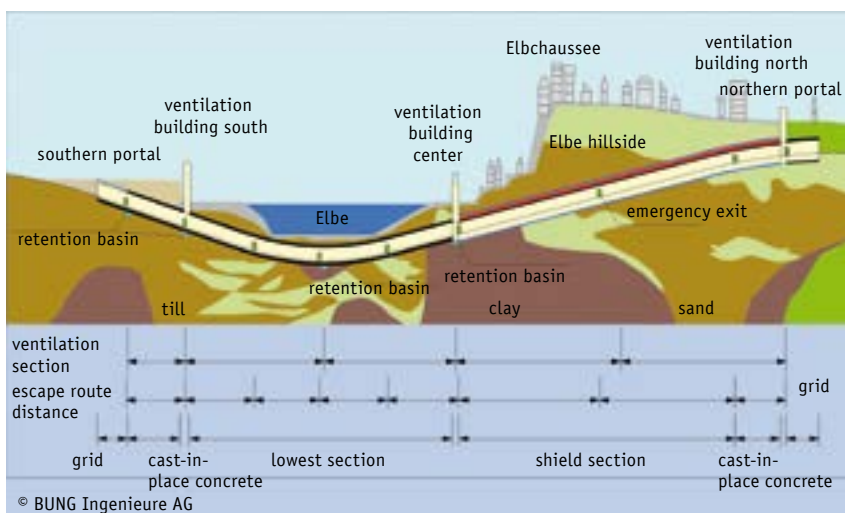
Fire protection retrofit for the Elbe Tunnel in Hamburg, Germany

After the devastating fire catastrophes in the Mont Blanc tunnel, the Tauern tunnel and the Gotthard tunnel, the EU reacted by enacting Directive 2004/54/EC "Road Tunnel Safety in the Trans-European Road Network," which set new standards in regard to fire protection.

A comprehensive retrofit of the first, second and third tubes of the 3,325 metre long tunnel was started in early 2009 to comply with the new directive and to improve safety in the Hamburg Elbe tunnel. TROX is supplying 410 tunnel dampers for smoke extract as part of the fire protection retrofit. The dampers are made of stainless steel and must withstand a temperature of 400 °C for 90 minutes.



Wall damper with integrated actuator



Project:
Owner:

*Hamburg Elbe Tunnel
Free and Hanseatic City
of Hamburg (D) LSBG
RMN and HBI Planning Bureaus*

Specialist consultant:

**General contractor and
HVAC contractor:**

*Cegelec Anlagen- und
Automatisierungstechnik
GmbH & Co. KG*

Smoke extract solution:

*Tunnel dampers with
dimensions of
2,050 x 1,600 mm to
500 x 6,250 mm*

► Full scale safety testing ►►

Test tunnel of Fundación Barredo, Spain

Tunnel Safety Testing S.A. operates the “Centro Experimental de San Pedro de Anes” testing station of the Fundación Barredo foundation in Siero in Asturias, Spain. In the 800 metre long tunnel, the use of ventilation systems during a fire, amongst other things, is being tested in full scale. Fans of normal designs and sizes are being tested in the test tunnel.

The tests are performed according to EN 12101-3:2002.

TROX equipped the test tunnel with 88 Type JF-P tunnel dampers with electric actuators.



Project: Test Tunnel,
San Pedro de Anes, Spain
Owner: Fundación Barredo
Specialist consultant: Fundación Barredo -
Engineering Dept.
General contractor and
HVAC contractor: OCA Construcciones y Proyectos
**Smoke extract
solution:** 88 Type JF-P tunnel dampers
with dimensions of
1,500 x 1,000 mm



Project: *Tunel Mrázovka, Prague, Czechoslovakia*
 Owner: *OMI MÚP*
 Specialist consultant: *SATRA spol. s.r.o.*
 General contractor and HVAC contractor: *Metrostav a.s.*
 Smoke extract solution: *Tunnel dampers with dimensions of 1,600 x 800 mm (combined in units of up to 8 x 10 m)*

ADAC

Very good

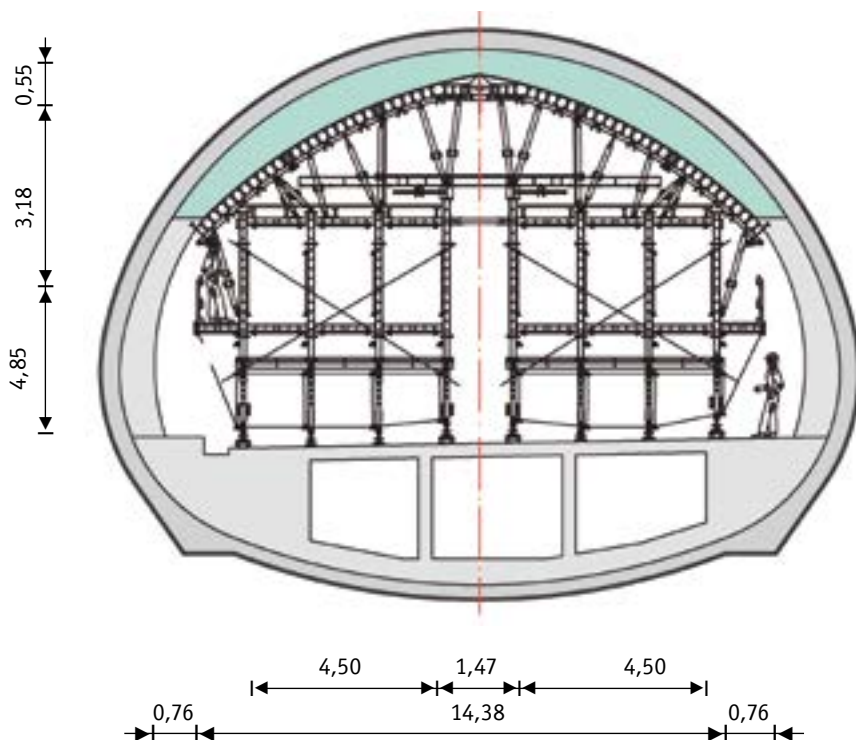
Test of 51 European tunnels EuroTAP 2007

► **ADAC rating: "Very good"** ►►

Mrázovka Tunnel in Prague, Czech Republic

The Mrázovka Tunnel is part of the Prague motorway circuit. It is about a kilometre long, has two tubes, and was opened in 2004. More than 45,000 vehicles, of which about 20 % are lorries, pass through the tunnel every day. A fire detection system automatically activates the smoke extract system in case of a fire and shuts the tunnel to further traffic. TROX provided the tunnel dampers.

In 2007, the ADAC gave the Mrázovka Tunnel a rating of "Very good" in the category of "Ventilation".



Tunnel damper with opposite coupling rods

► A quantum leap in regard to safety ►►

The Juan-Carlos-Tunnel in Vielha, Spain

The 5,230m-long Juan-Carlos-Tunnel in Vielha, Spain, is part of the N-230 and is situated in the Pyrenees. It has three lanes and an incline of 4.57%. The tunnel is monitored around the clock by a control room with cameras.

The new Juan-Carlos-Tunnel replaces the old tunnel, which was opened in 1948 and, despite numerous improvements, was no longer able to meet a contemporary safety standards. In future, it will be used as an escape tunnel and is connected to the new tunnel by a 70m-long walkway.

The entrances to the evacuation walkways are located every 400 metres, whilst fireproof rescue niches can be found every 200 metres. To enable people to save themselves in case of a fire, the new tunnel was equipped with a high-performance smoke extract system. For this purpose, TROX supplied 99 Type JF-P tunnel dampers in stainless steel 1.4571 with electric actuators.

In 2009, the ADAC gave the Juan-Carlos-Tunnel a rating of "Very good" in the category of "Ventilation". In comparison with the old tunnel from 1948, which regularly landed in last place in the ADAC tests, the new tunnel has made a quantum leap in regard to safety.



ADAC

Sehr gut

Im Test 51
europäische
Tunnel
ADAC 2009

Project: Juan Carlos I Tunnel
Owner: Ministry for Public Works, Spain
Specialist consultant: IDOM and CEMIM (Fundación para fomento de innovación industrial)
General contractor and HVAC contractor: OHL, S.A. – COPCISA, S.A. – COMSA, S.A.
Smoke extract solution: 99 Type JF-P tunnel dampers with dimensions of 2,000 x 750 mm



Project: U2 Schottenring and Taborstraße
Owner: Wiener Linien GmbH & Co KG
Specialist consultant: TIWAG Tiroler Wasserkraft AG
General contractor and HVAC contractor: Getec Energie- & Gebäudetechnik GmbH

Smoke extract solution: 56 tunnel dampers with dimensions of 2,400 x 1,800 mm

Praterstern Train Station, Vienna, Austria

► Under the streets of Vienna ►►

Underground stations in Vienna, Austria

For the building of the new "Praterstern" and "Schottenring" underground stations in Vienna, 56 galvanised and powder coated Types JF-S and JF-P tunnel dampers with electric actuators were used. The project was managed by TROX Austria and completed in 2007.



Tunnel damper with opposite coupling rods



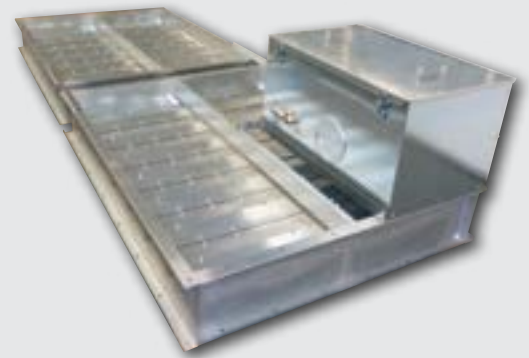
Underground station "Schottenring," Vienna, Austria

► Safety at five-minute intervals ► ►

Underground railway stations in Amsterdam, the Netherlands

The Amsterdam underground railway system transports about 300,000 passengers a day. The network consists of 52 stations. Five underground stations of Line 53 and their ten entrances in total were renovated in 2010/2011 and equipped with modern fire and smoke protection systems.

In total, 115 TROX tunnel dampers, with actuators and thermal insulation enclosures, were installed in the stations.



Wall damper unit with thermal insulation enclosure



Project: Metro Oostlijn Amsterdam
Owner: GVB Exploitatie BV
 (Central Public Transit Authority)
Specialist consultant: ARCADIS

General contractor and system builder: Wolter & Dros

Smoke extract solution: 115 JF-P tunnel dampers with dimensions from 2,000 x 420 mm to 2,200 x 1,125 mm (combined in units of 8.9 x 2.6 m)



Project: Heslacher Tunnel,
federal highway B14
Owner: Baden-Württemberg
state capital Stuttgart
Specialist consultant: HBI Haerter AG, Heidenheim
**General contractor
and system builder:** OSMO-Anlagenbau GmbH & Co. KG

**Smoke extract
solution:** 38 JF-P tunnel dampers
with dimensions of 2,000 x 1,530 mm
(36 for ceiling installation,
2 for wall installation)

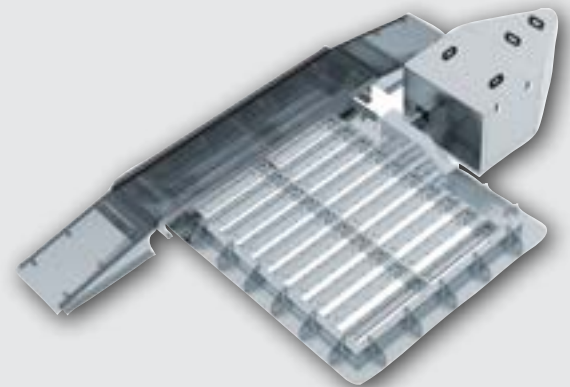
► Safe in oncoming traffic ►►

The Heslacher Tunnel in Stuttgart, Germany

Every day, about 50,000 vehicles pass through the Heslacher Tunnel in the south of Stuttgart. The tunnel is part of federal highway B14 and one of the main traffic arteries of Stuttgart, the state capital of Baden-Württemberg. It consists of a tunnel tube and is operated with oncoming traffic.

With extensive retrofitting measures, the tunnel technology is being brought to the level of RABT 2006. In the process, a completely different ventilation and safety concept is being realised.

During a fire, fire gases are removed through remote-controlled TROX tunnel dampers in the false ceiling. The dampers are arranged at intervals of about 100 m and can be opened along a length of about 250 m. Two dampers are located in the side wall of the tunnel. 38 smoke extract dampers were installed in total.



*Ceiling damper with installation subframe,
thermal insulation enclosure and adapter*



► Released for hazardous materials ►►

The Pörzberg Tunnel near Schaala in Thuringia, Germany

With the expansion of the L1048, the tri-city area of Saalfeld, Rudolstadt and Bad Blankenburg was better connected to the highway network. Here the Pörzberg Tunnel, which opened in 2010, avoids a bottleneck in the city of Schaala.

Since the tunnel is operated with oncoming traffic and has been released for hazardous materials, an automatic pneumatic foam extinguishing system was installed along the entire length. In addition, two fire trucks designed for this tunnel are available at all times. Particularly high safety requirements apply for the ventilation system in accordance with RABT 2006.

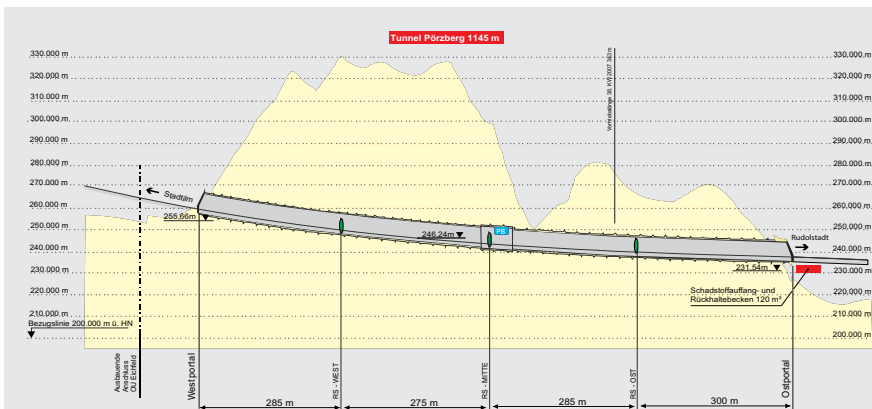
A smoke extract channel has been installed along the tunnel ceiling for a length of 924 m. It is separated from the driving area by a cemented false ceiling. At intervals of about 50 m, 17 remote-controlled TROX tunnel damper units have been installed in the false ceiling. The highly air-tight TROX tunnel dampers permit smoke extract along a distance of about 200m in the vicinity of the fire, whilst the rest of the tunnel remains smoke-free for the most part.



Ceiling damper unit on the driving side



Domed end cap of ceiling damper unit



© SW Ingenieurbüro Brandschutz GmbH

Project: Pörzberg Tunnel
Owner: Straßenbauamt Mittelthüringen

Specialist planner: GBI Engineering Consultants
Specialist consult for ventilation and smoke extract: Kündig Ingenieurbüro, Switzerland
General contractor and system builder: Siemens Building Technologies GmbH & Co. OHG

Smoke extract solution: 34 JF-P tunnel dampers with dimensions of 1,185 x 1,760 mm (combined in 17 units of 2.7 x 1.9 m)

► TROX projects

Road tunnels ►►

- Elbe Tunnel, Hamburg, Germany
- Pörzbergtunnel, Thuringia, Germany
- Juan Carlos I motorway tunnel, Vielha, Spain
- Urban freeway M-30, Madrid, Spain
- Connecting tunnel Calle de Embajadores–A4/M-40, Madrid, Spain
- Eastern Harbour Road Crossing, Hong Kong, China
- Tate's Cairn Road Tunnel, Hong Kong, China
- Lion Rock Road Tunnel, Hong Kong, China
- Melbourne City Links, Melbourne, Australia
- Chongqing Road Tunnel, Chongqing, China
- M5 Road Tunnel, Sydney, Australia
- Tunnel du Fréjus, France
- Pfänder Tunnel, Bregenz, Switzerland
- Mrázovka Tunnel, Prague, Czech Republic
- B14 Heselach Tunnel, Stuttgart, Germany
- Grouft Tunnel, Luxemburg
- Saukopftunnel, Weinheim, Germany
- Leifers Tunnel, Bozen, Italy
- Schallberg Tunnel, Switzerland



Tate's Cairn Tunnel, Hong Kong



Metro, Copenhagen



Melbourne City Links, Melbourne



Station Canary Wharf, London

► Other projects ►►

- Strategic Stores – Underground Storage Facility, Saudi Arabia
- AWE Aldermaston, Aldermaston, UK
- Porton Down Containment Facility, Salisbury, UK
- BNFL Sellafield Drypack, UK
- North Sea Claymore platform
- BNFL, Devonport, UK



Mrázovka-Tunnel, Prag



Stazione Milano Repubblica, Mailand



Pfändertunnel, Reihntal/Walgau



Lion Rock Road Tunnel, Hong Kong

► TROX projects

Railway and metro tunnels ►►

- Berlin Brandenburg Airport, Germany
- U4, Hafencity, Hamburg, Germany
- Kowloon Station, MTR Airport Express, Hong Kong
- Lai King Station, MTR Airport Express, Hong Kong
- Chek Lap Kok Ground Transp. Centre, MTR Airport Express, Hong Kong
- Taipei Metro MTR 308, Phase 1 und 2, Taipeh, Taiwan
- Metro Milano, Phase 2, Italy
- Metro station Praterstern, Vienna, Austria
- Metro station Schottenring, Vienna, Austria
- Metro Copenhagen, Denmark
- KCRC SI-1200 West Rail, Hong Kong, China
- Statentunnel, Rotterdam, The Netherlands
- Metro line U2 Volkstheater, Vienna, Austria
- Metro line U2 Museumsquartier, Vienna, Austria
- Metro line U1 Reumannplatz, Vienna, Austria
- Wienerwald Tunnel, Austria
- Perllongament Tarrasa, Spain

- BNFL BTC, Sellafield, UK
- Test tunnel of Fundación Barredo, Spain
- Linth-Limmern Power Stations, Switzerland
- Kaprun Limberg II Pumped Storage Power Plant, Salzburg, Austria
- VW Paint Shop, Zwickau, Germany
- Ulm University, Germany



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