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Fire Protection in Traffic Tunnels: Resu of EUREKA Research Project EU 499 FIRETUN"

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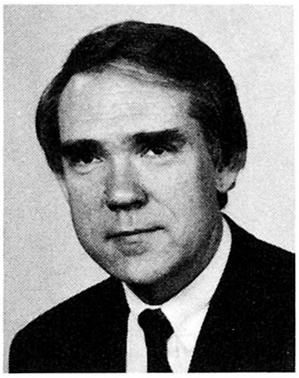

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Summary

Against the background of increasing problems concerning the safety in underground transport facilities 9 European nations cooperated in the EUREKA project EU 499 FIRETUN. Their common efforts formed the basis for a remarkable condensed instrumentation of a 2300 long test tunnel. Altogether 21 tests were conducted between 1990 and 1992 and evaluated during 1993 through 1995. Many important results were gained and published inbetween. They form a strong basis for international discussion on fire safety concepts.

1. Introduction

Fire in traffic tunnels (road or rail), are an international problem. They are characterised by the danger they present to the persons affected and, in many cases by the considerable amount of material damage that they cause (see Fig. 1). Serious accidents resulting in injuries have been individually reported from France, Great Britain, Japan, Canada and the U.S.A. Various major fire accidents have also occurred in tunnel facilities in Germany. These cases have served to draw attention to the possibilities of escape and rescue, which are made more difficult in a tunnel scenario.

Serious fire cause considerable material damage, not only to rolling-stock or vehicles, but often to the tunnel facilities as well. This damage is brought about by the massive development of heat and aggressive combustion gases, among other causes. Although the effects of fire seldom threaten the stability of a tunnel structure, they often reduce the availability of the tunnel for traffic, at least for a certain length of time.

The effects of this latter aspect should on no account be underestimated. In some cases, redevelopment can take weeks or months. If as a result, service in important tunnel sections of a metro or urban commuter network has to be discontinued, the inevitable result will be serious disturbances in their everyday operation in built-up areas (such as Berlin, London, Paris or Vienna). As a consequence, in Germany the "Guidelines for Furnishing and Operating Road Tunnels" [1] expressly point to the effects of a case of fire and consequently call for suitable measures already within the scope of preventive fire protection.

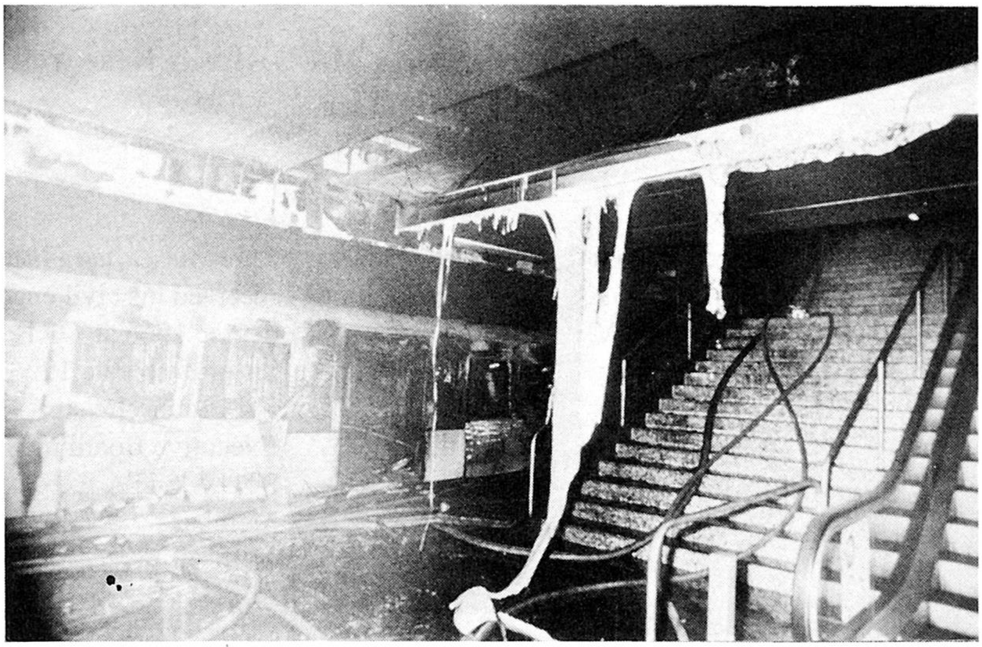

Fig. 1 Destroyed vehicles and interior furnishings at a stop following an urban commuter train fire on April 8, 1980 in Hamburg, Germany

2. Rate of Risk

According to statistics of the late eighties the probability of a fire accident in traffic tunnels can be assumed as follows: 1 case per 10^{10} km regarding road traffic and 1 case per 0,5 x 10^{9} km regarding railway traffic. In the field of passenger transport the risk with car traffic can be assumed as being about 20 to 25 times as high as that of railway traffic. Additionally and generally speaking, it has been determined that the risk of fire in traffic tunnels is on the increase. The reasons for this are:

- The growing density of traffic, especially on the roads.
- The increasing travelling speeds in rail traffic.
- The already high (Table 1) and steadily growing number of tunnels, with ever greater individual lengths.
- Increasing of vandalism, including increasing a trend towards terrorism (witnessed, e.g., in cases of arson).

Such developments must be taken into consideration in developing a safety concept for tunnel traffic.

3. Amount of Tunnels

This becomes still clearer by looking closer to the situation of recent and future tunnelling in Europe:

Numerous rail and road tunnels are in operation (Table 1) or are being built in various European countries. As examples, the following major projects are either in operation, under construction or in the planning stage:

- The Channel Tunnel (rail) between Britain and France, which is approximately 52 km long.
- The Great Belt Tunnel (rail) in Denmark, between the islands of Funen and Seeland, which is about 7 km long.
- The Alpine transit routes for rail traffic in Austria/Italy (the Brenner Base Tunnel) and in Switzerland (where the Gotthard Base Tunnel and the Lötschberg Tunnel are being contemplated), each approximately 40 to 50 km long.
- Mt. Cenis Tunnel as an additional Alpine transit between Lyon (France) and Turin (Italy) with an estimated length of 54 km.
- A recently discussed special tunnel for transport of goods between South-Germany and North Italy (Tunnel Tyrol) with a total length of about 150 km.
- A tunnel undercrossing the Oresund between Denmark and Sweden with a length of 4 km.
- A tunnel between France and Spain undercrossing the Pyrenees along the route between Narbonne and Barcelona with a total length of about 12 km.
- The Gibraltar Tunnel between Spain and Morocco, which will prabably be about 50 km long.
- A large number of tunnels within the framework of the planned pan-European high-speed rail links, scheduled to be completed by the year 2015 [2].
- Various tunnels planned in Norway beneath straits in order to connect islands with one another or with the mainland; the overall length will be greater than 100 km. A number of these tunnels will be more than 10 km long and will be constructed at depths of 600 m and more below sea level [3].

Taking all these new construction measures into account, the pan-European traffic tunnel network is likely to far exceed 10,000 km by the year 2000.

Traffic tunnels (route km)				
	Metro	Rail	Road	Total
Austria	15	105	210	330
Switzerland	-	360	140	500
Germany	550	380	70	1000
France	270	650	180	1100
Great Britain	200	220	30	450
Italy	60	1150	600	1810
Norway	20	260	370	650
Spain	200	750	100	1050
Total	1315	3875	1700	6890

Table 1 Rail and road tunnel operations in various West European countries (status 1990)

4. Generalities of the EUREKA-Project

Against the background described above, and in consideration of the fact that subsurface traffic facilities are increasing in number, length and number of users, ministries in Germany and other countries have commissioned a comprehensive survey in order to improve fire protection in subsurface traffic facilities - something urgently required throughout Europe.

In Germany, iBMB (Institut für Baustoffe, Massivbau und Brandschutz) at the Technical University of Braunschweig started about 1970 first theoretical studies into the fire process in tunnels and continued its efforts in midth of the 80ies in cooperation with STUVA (the Research Association for Underground Transportation Facilities, Inc., Cologne) by planning and preparing experimental tests. After strong rejection by the environmentalists in Germany the tests were conducted in an abandoned transport tunnel in the north of Norway.

The Technical Research Centre of Finland, Fire Technology Laboratory at Espoo and the Norwegian Road Research Laboratory in Oslo were also involved in the project. Finally, other European countries such as Austria, France, Great Britain, Italy, Sweden and Switzerland joined the project and supported it. Their contribution consisted of additional tests and back-up technical equipment for test tunnel measurements within the scope of a jointly sponsored project.

The EUREKA-project EU499 FIRETUN (in the following: EUREKA tests) can be seen in a certain sense as a continuation of former European full scale tests in the 60ies and 70ies as they were conducted in the Ofenegg Tunnel (Switzerland) in 1965 [4] and in the Zwenberg Tunnel (Austria) in 1976 [5]. In both cases petrol pool fires were performed to investigate the smoke movement along a tunnel dependent on the air velocity. They gave important answers to the question of dimensioning mechanical ventilation systems especially in road tunnels. Directly continued are the Ofenegg-Tunnel and the Zwenberg-Tunnel Tests by those conducted in the Memorial Tunnel, West Virginia, USA, during 1993 to 1995. In these tests the main modes of mechanical ventilation systems (longitudinal, semi-transverse and transverse) are simulated with tremendous financial efforts [6]. Again, here are used petrol pool fires, in this case with a fire load up to 100 MW, so, taking all these full-scale test series, the EUREKA tests were the only ones using real today's vehicles as fire load.

5. Most Important Findings

The evaluation of the international test programme was finished in 1995 and published in an international English written report. The most important findings have been established as follows [7, 8]:

1. The influence of damage both to the vehicles and the tunnel lining, especially in the crown area, depends on the type of car. This fact, already derived from numerous fire accidents was entirely confirmed by the tests in Norway. The roof of those vehicles constructed of steel resisted the heat, whereas the roofs of the public bus and of a metro car both made of aluminium were completely destroyed at a rather early stage of the test fire. The same happened, as expected, to the roof of the private car with a plastic body (see Fig. 2).

2. The temperatures during most of the rail car and bus fires reached maximum values of about 800 to 900 °C, in one case about 1000 °C. Against this the temperature during the test with the heavy good vehicle loaded with 2 t of modern furniture climbed up to more than 1300 °C (Fig. 3). Along the tunnel, temperatures decrease over a relatively short section. For escape, the situation is worse downwind than upwind.

3. The size of the fires has been recalculated on the basis of the Swedish and Norwegian measurement of heat release. The rail car fires mostly amounted to between 15 and 20 MW, the burning of the heavy good vehicle was measured more than 100 MW. This leads to the values given in Table 2.

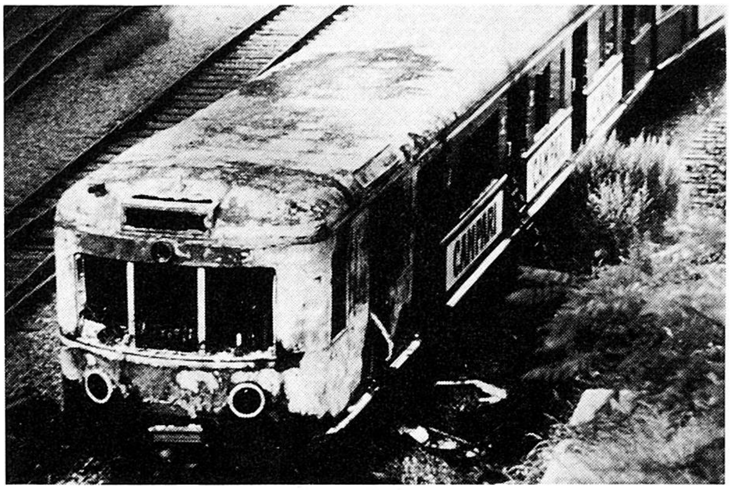

Fig. 2a
All-steel body; fire accident on July 24, 1979, on the Hamburg urban commuter system

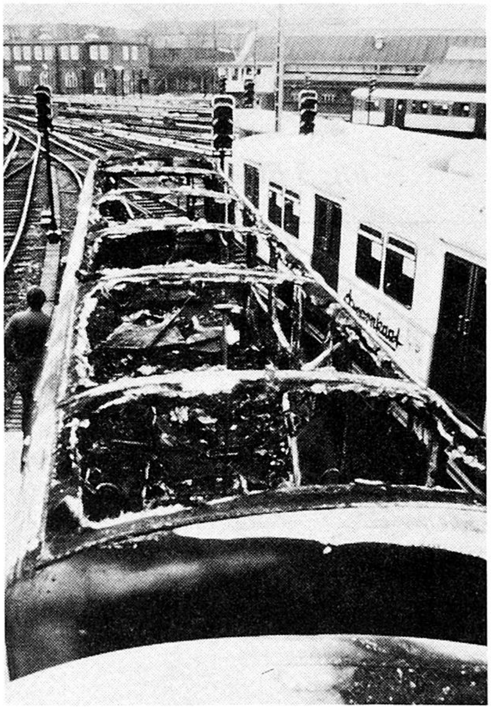

Fig. 2b
Fiber-glass-reinforced plastic in the roof section; fire accident in the Hamburg metro on April 11, 1979

Fig. 2c
Aluminium body; fire accident on April 8, 1980, on the Hamburg urban commuter system

Fig. 3 Fire test on a heavy good vehicle loaded with 2 t of modern furniture

Type of vehicle	Max. temperature [°C]	Max. calorific power release [MW]
Passenger car	400 - 500	3-5
Bus/lorry	700 - 800	15-20
Heavy lorry (HGV) with burning goods (not petrol or other harzardous goods)	1000 - 1200	50-100
railway coaches	800 - 900	15-20

Table 2 Most important results: maximum temperatures and maximum momentary rates of heat release [7]

4. All the rail and road car fires registered a fast development during the first 10 to 15 minutes. So, seen from the aspect of temporal development and heat emission, the hydro carbon curve of RABT covers the reality much better than the unit temperature curve of DIN 4102 (see Fig. 4). But, in this connection, there is one question not yet answered. The European countries have to discuss and think it over, if the Dutch design curve - especially taken for the static calculation of underwater tunnels - with its maximum temperature value of 1350 °C, is closer to reality than the RABT curve in Germany with its highest temperature value of 1200 °C. This question arose as a consequence of the test with the heavy good vehicle.

5. Modern outfitting of rail cars makes them much more resistant against ignition than that of earlier vehicle generations. This could be proved by the fire tests with two halves of German Federal Railway passenger coaches, which both had all-steel bodies but with different lining materials for their walls and roof. The two latter-mentioned test vehicles were stripped off seats and other internal furnishings in order to obtain a true comparison of the influence of the roof and wall lining materials.

   The coach lined with materials based on fibre-glass reinforced, unsaturated polyester, in accordance with the latest state of technology, developed a considerable fire. However, the other coach, lined with materials based on a phenol resin basis, which releases energy at a lower rate, proved to be flame-resistant. In both cases, an ignition energy of approximately 6 l isopropanol (= 7,293 cm³, corresponding to 200 MJ = fire load of a seat) was applied. The phenol resin lining did not catch fire, even after the ignition energy was doubled.

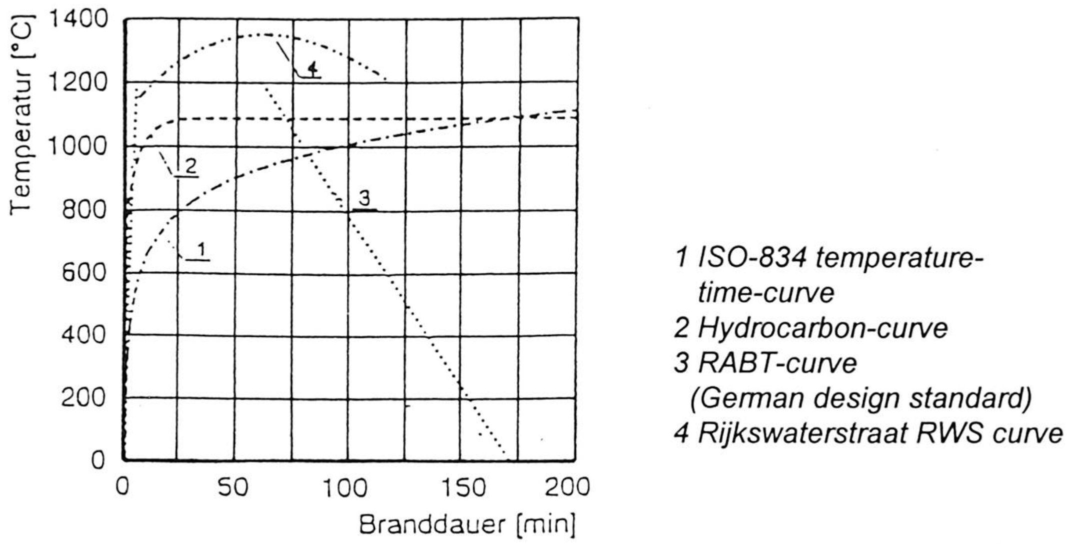

Fig. 4 Comparison between the time-temperature curves of RABT, the Dutch RWS, a hydrocarbon fire and ISO-834/DIN 4102

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