“FROM THE CLASSICAL FIRE-FIGHTING WATER SUPPLY TO STRUCTURE AND SMOKE-GAS COOLING, TAKING THE “GLEINALM TUNNEL” AS AN EXAMPLE, PART I

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1. INTRODUCTION AND OBJECTIVE

Classical fire-fighting water supply systems have not been able to prevent disasters in road tunnels. The first 10 to 15 minutes are crucial in fighting fires. However, the persons involved are normally not capable of becoming active in initiating fire-fighting measures on scene. Moreover, activating hydrants and handling the equipment requires expertise and training. Against this background, there are considerations for the use of water-spray systems, etc. as a first means to quench the fire. After giving an overview of the currently existing fire-fighting water supply systems, this option will be discussed based on these systems. In the Gleinalmtunnel, smoke-gas cooling by injecting fine dripped water mist is being implemented to protect air extraction facilities. (see presentation by Helmut Kern).

Classical water supply systems are imperative for fire brigades in combating fires and in mitigating their consequences. Naturally, avoidance of the outbreak of any fire is the overarching goal. In the event of a fire, recognizing and localizing the incident have absolute priority. The same applies to the ventilation system, which has to be adapted to the fire incident to minimize the spread of the fire and the development of smoke. If the fire is not detected early enough and if no immediate action to extinguish it is taken, it must be safeguarded that the victims are able to reach the exit, escape adits or emergency bays via the shortest route. Another absolute requirement to protect humans and material in tunnels is to provide and to keep clear the access routes for professional fire fighters.

2. FUNDAMENTALS, GUIDELINES AND STANDARDS

2.1. Scope of application

Applicable to existing and planned road and railway tunnels, not to subways, etc.

2.2. Terminology, definitions, etc.

- Mountain tunnels
- Underground passages (flat land tunnels)
- Underwater tunnels
- Short tunnels up to 800 m
- Tunnels of medium length: 800 to 2.400 m
- Long tunnels 2.400 to 9.600 m
- Extremely long tunnels > 9.600 m
- Twin-bore tunnels
- Single-bore tunnels
- Cross passages
- Escape tunnels / exploratory tunnels
- Longitudinal ventilation
- Transverse ventilation
- Fire extinction bays
- Parking bay with rescue and waiting area

2.3. Guidelines, standards, etc.

- RVS (Austrian Guidelines and Regulations for Road-based Infrastructure)
- Guidelines for fire protection, guidelines and standards for the planning, construction and operation of water-supply systems, etc.
3. DESIGN PRINCIPLES AND COMPONENTS OF A CLASSICAL FIRE-FIGHTING WATER SUPPLY SYSTEM ACC. TO RVS

![Diagram of classical fire-fighting water supply system]

**Fig. 1:** Classical fire-fighting water supply system

3.1. Water requirement, supply pressure, bay equipment, etc.

According to RVS, hydrants must be able to deliver 1,200 l/min at a flow pressure of 6 to 12 bar for a period of 1.5 hours. Experience has shown that this quantity is sufficient for the conventional method of fire-fighting via hydrants. Pressures above 6 bar should be avoided as handling hoses at such admission pressures may be dangerous. When determining the admission pressure and the water quantity, the equipment available in the bays and in the tunnel itself as well as the equipment of the fire protection staff needs to be considered, too. It should be noted at this point, that in long tunnels large water extraction volumes and high admission pressures require lines of a diameter of DN 200 to DN 250. The equipment of fire brigades is usually at a standard which allows water quantities and pressure to be increased to the required level via mobile pumps anyway. The use of foam could be optimized.

3.2. Availability of water resources and water procurement

Basically, there are 3 common ways of water procurement in Austria:

a) Obtaining water from an existing water-supply company (municipal water supply, water cooperative or association, individual water supply companies)

b) Building a separate water procurement system (spring water, ground water, surface water) – see photo 1

c) Using the tunnel’s sidewall water

Even though drinking water quality is not required for fire-fighting water supply systems, their water quality must be similar in its physical and chemical properties to drinking water since, for example, corrosion and depositions may have adverse effects on fire-fighting water supply systems, too (pipe ruptures, service life, ...). Moreover, a part of the fire-fighting water supply system is also used to provide tunnel operation facilities with drinking water, so that drinking water quality is a requirement in this case.
From a hydraulic-economic point of view, water procurement facilities which are located at altitudes above water storage facilities are to be preferred as this eliminates the need for pumping. On the other hand, considering the low annual consumption, the water transport costs are not really an issue for fire-fighting water supply systems.

When extracting the tunnel’s sidewall water, it must be borne in mind that in case of karst catchment areas the water may turn very turbid after precipitations, rendering it partly or completely unsuitable for use. Another problem which may arise under special circumstances is sintering and the vanishing of the sidewall water, particularly if it is subject to strong fluctuations. In this case it may dry up almost completely at low water. This problem does not usually occur when the bedrock is crystalline; however, this water is mostly highly aggressive. In both cases, appropriate measures must be taken to prevent corrosion and deposits. If water is obtained from public utilities, these concerns are unfounded.

3.3. Water storage (see photo 2)

RVS specifies that 108 m³ of water must be available for a period of 1.5 hours and that this volume must be replenished within 24 hours. This means that an inflow of approx. 1.2 l/s is required. Taking into account the quantities needed for cleaning and for tunnel operation facilities, the storage volume is normally designed for a capacity of 150 m³. If water is available in greater abundance, the storage volume can be reduced accordingly.

As a matter of principle, twin-chamber elevated tanks are to be preferred as this safeguards the security of supply even in case of power failure. Theoretically, the water for the purpose of fire-fighting could be supplied directly by a third-party utility without the need of building one’s own water procurement system and one’s own storage facility. This is probably the reason why a provision is included in RVS requiring dual supply, as the security of supply might not be guaranteed if one relied on the direct source of supply alone. Such a situation could arise, for example, if the tunnel were connected to a utility operating with ground tanks. In the event of a power failure, the fire-fighting water supply would fail as well.

Based on his own experience, the author would recommend installing a separate fire-fighting water tank for the sake of the necessary security of supply. Whenever and wherever elevated tanks are not possible, an adequate water supply must be safeguarded by ground tanks, which
must be provided with an appropriate pumping system. In long tunnels, the pumping station must be protected from power failure (emergency power generator).

**Fig. 3:** Water storage basin (by Markus Gutjahr, Asfinag)

### 3.4. Pipelines

For reasons of fire protection, the only eligible material candidates are cast iron and steel lines, which, however, should not be coated with material containing PVC. Cast iron and spheroidal graphite iron have proved their worth in numerous tunnels, and their benefit versus steel pipes is their wall strength. In Germany and Northern Europe GRP pipes are used as well. However, in my view these pipe materials should be investigated further via fire tests to collect further data and, based on these, choose the right material. As already mentioned, a diameter of 150 at a minimum and of 200 at a maximum ought to be sufficient.

Hydrants must be placed at distances of 100 to 150 m as well as at the portals. The equipment of the bays should be coordinated with the fire brigade. Hose systems, foam and fire-fighting tubes may be stored in the bays as well, if required. Time and again discussions arise on how to design and equip the bays as temporary shelters. The author would rather recommend the provision of parking bays at distances of 500 m and equipping these with rescue and waiting rooms. This would be desirable in long single-bore tunnels, whereby the bays should be provided on both sides, but always at half the distance, so that in essence there would be a parking or rescue bay every 250 m. These bays must be provided with air via a compressed-air system, which may also be used to control valves and gates (e.g. in case of power failure). In twin-bore tunnels, closed-loop connections must, of course, be established via cross passages, etc.

### 3.5. Technical safety equipment, especially in the hydrant bays (see photo 3)

The equipment depends on the length of the tunnel, on the distances between the bays and on the hazard classification of the tunnel.

The basic equipment should include:
- hoses and hose drum with dimensionally stable hose
- foam with admixing device, steel pipes, etc.
- various hand-held fire extinguishers, etc.
The fire extinguishing bays are marked by an appropriate signaling system, which must switch to flash mode in case of a fire. The author strongly suggests that training how to behave in case of fire should become mandatory for learners at driving schools.

Barendrecht Tunnel / railway tunnel in the Netherlands

Fig. 4: Hydrant bay with downpipe to sprinkler system

3.6. Control and operation

Normally, hydrants are operated by trained personnel. According to RVS, there are lines which are permanently filled with water and so-called dry-lines which are filled in case of a fire. It would be important to clarify whether these so-called dry lines will be filled automatically at the outbreak of a fire or on activation by the fire fighters on site. For operational reasons the author would favor wet lines. To detect any problems in the firefighting system as early as possible, selected parameters should be permanently monitored, such as the water level in the elevated or ground tank and electrically driven components of the system (pumps, valves etc.). Collecting these data and transmitting them to a permanently-staffed tunnel control center is an absolute requirement.

At regular intervals the overall systems should be inspected for reliable performance by the tunnel staff. This applies, in particular, to the mobility of gates and of shut-off and reducing valves, which should be checked, as well as to the equipment in the fire extinguishing bays. Moreover, the fire brigades should have knowledge of other possible ways of water procurement existing in proximity to the portal area (e.g. rivers, reservoirs, etc.). Special attention must be paid to the metallic parts of the fire-suppression lines, which must be properly grounded to prevent the risk of electric shocks. The annual and routine checks including remarks, in particular as regards damage and repair, should be recorded, and these records should be collected and evaluated throughout Austria.
A problem which must not be underestimated is the removal of the consequences of a fire, in particular the possible discharge of fire-extinguishing media into the road drainage and, further on, into ground water protection zones and receiving waters. At any rate, precautions must be taken to prevent extinguishing media and the resulting chemical compounds from entering the natural cycle.

4. EXPANDING AND IMPROVING FIRE PROTECTION BY SPRINKLER AND SPRAY SYSTEMS

Sprinkler and spray systems have proved to be very efficient in commercial and industrial buildings, so that their use in tunnels should be considered as well. Sprinkler or spray systems could be positioned on the roof or on the sidewalls of the tunnel between the bays and connected to the fire extinguishing line. If required, they could be activated, for example, for certain tunnel sections. Tests should be performed to investigate whether this would limit the rise in temperature to levels which would not only protect humans, but prevent damage to objects as well. We all know only too well how time-consuming and costly it is to repair concrete structures.

The advantage of sprinkler and/or water spray systems operating at high pressure is that they disperse very small water droplets across long distances, thus counteracting efficiently the spread of heat and fire. Marioff provided the following data on the systems:

A water mist system was applied in the exhaust air duct of the Gleinalmtunnel in order to cool down fumes in case of a fire. A detailed description of this system can be found in the paper “From Classical Fire Fighting Water Supply to structure and smoke gas cooling taking Gleinalmtunnel as an example” of Mr. H. KERN; AQUASYS Technik GmbH, Linz Austria
5. SOME REFLECTIONS ON TUNNEL SAFETY AND PROPOSALS FOR IMPROVEMENT

5.1. The cardinal sins committed during the Kaprun disaster (from “Blaulicht” 12-2002)

- Carriage doors and windows could not be opened from inside.
- No automatic safety doors that would open automatically in case of an incident.
- No safety hammers to smash the window panes.
- No fire extinguishers mounted in the passenger compartments.
- No tunnel illumination and no emergency lights.
- No after-glowing rescue information and signs, neither in the tunnel nor in the train.
- No rescue stairs in the tunnel. The existing stairs were merely service stairs for maintenance work and not at all suitable for rescue operations!
- No rescue or safety caverns in the tunnel.
- No sprinkler system in the tunnel or in the train.
- Tunnel lock at the top station open, presumably due to the destruction of the energy source by the fire (dead-man circuit). Thus, strong chimney effect.

**Fig 6:** Comparison of a sprinkler and spray systems

<table>
<thead>
<tr>
<th>Typical drop size range (mm)</th>
<th>Number of droplets per litre of water</th>
<th>Surface area (m²)</th>
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<tbody>
<tr>
<td>1...5</td>
<td>15 thousand to 2 million</td>
<td>1...6</td>
</tr>
<tr>
<td>0.2...1</td>
<td>2 million to 250 million</td>
<td>6...30</td>
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<tr>
<td>0.025...0.2</td>
<td>250 million to 150 billion</td>
<td>30...250</td>
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<th>Superior cooling and local inerting</th>
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<td>Superior blocking of radiant heat</td>
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5.2. Escape and rescue routes and exiting and rescue times

Fig 7: Allocation of the escape and rescue times

Phases of the fire and necessary protection for people
From: Leitfaden Ingenieurmethoden des Brandschutzes vfdB TB 04-01, issue May 2009

Fig 8: Overview of escape and rescue routes

By courtesy of Univ.-Lecturer Dr. Otto Widetschek