Tunnel Questions?

By David Lane. MIFireE

Inside Kaprun tunnel post the fire, showing the extent of damage caused by a fully developed fire.

Pic courtesy of ASTV video.

What's the Problem with Tunnels?

All tunnels can become a fire related problem sometime in their long lives – a relatively straightforward assumption? Asks David Lane. Given the track record for firstly road tunnels – in January 2000, AIT/FIA (the European motoring organisation) commissioned Deutsche Montan Technologie GmbH (DMT) to perform a second tunnel test survey. A total of 25 tunnels were examined in eight European countries. The report stated in amelioration that compared to open roads and motorways, the risk of accidents in road tunnels is minor. Statistics showed that fewer accidents happen in tunnels than on open roads. This is primarily due to the minimum effect of weather conditions, to speed limits, steady lighting conditions, as well as the low number of junctions/links in tunnels. However, even small accidents are difficult to manage in tunnels, particularly for rescue personnel (ambulance personnel, fire brigade, police etc.) by having very restricted access. Accidents resulting in fire can lead to a disaster – as events in Montblanc, Leinbach and Tauern Tunnels demonstrated.

Next, railway tunnels, after these devastating fires, safety standards in Swiss tunnels (both road and rail) were the subject of a detailed study conducted on behalf of the Department of the Environment, Transport, Energy and Communications (UVEK). In 1999 the Federal Transport Office (BAV) launched a further study related to safety in rail tunnels. Their analysis of rail tunnels showed:

- 16% of the 689 tunnels reviewed were rated as having safety problems – a staggering 110 tunnels
- In 26 tunnels, most of them over 3000 metres long, the BAV also considered additional measures to be warranted with regards to facilities for rescue. These included:

  a. footpaths and handrails
  b. lighting (emergency)
  c. ventilation
  d. marked escape routes.

The past few years have seen an appalling succession of major fires in tunnels with casualties, some being:

1995	Baku Subway	289 dead
1996	EuroTunnel	0 dead
1999	Mont Blanc	39 dead
1999	Tauern	12 dead
2000	Kaprun	155 dead

A Fogtec high pressure water fogging gun in action on a test fire.

Pic courtesy of Fogtec Gmbh

THE PROBLEM?

In fire conditions the firefighter/engineer/safety manager knows that the rate of heat release, the smoke and gas concentrations and rapid fire propagation creates an environment dangerous to human life. Carbon monoxide and "hazmat" generation in fire effluent can rapidly reach dangerous levels. Tunnels are designed in so many shapes, curves and elevations between portals. Many parameters impinge and weather conditions; traffic density and traffic speed are important factors in a fire's cycle. We are all aware of the risks connected to the transportation of dangerous materials like flammable liquids and chemicals, and it is common knowledge that flammable gasses and vapours can form explosive mixtures when mixed with air. However, it is less widely recognized that every day materials such as flour, coffee, sugar, cacao and milk powder could form dust clouds, which are liable to explode with serious consequences. It is also important to consider HGVs transporting materials like wood pallets; wood chips and different plastic products, which are not in themselves considered dangerous, but

Pic courtesy of Securiton AG

will in a fire situation, represent a considerable additional fire load. Commonly transported by road or rail vehicles. The German BIA report "Brenn und Explosionsgrossen von Stauben" showed that a dust explosion can occur if a cloud of combustible dust is ignited by heat application, flame or spark – small amounts of energy being sufficient to start an explosion, typically > 10mJ. Also the pressure wave arising from an initial explosion can raise a much larger dust cloud, which can then fuel a catastrophic secondary explosion.

Tunnel fires can generate massive amounts of destructive power, conditions are ideal for smoke spread, rapid increases in radiated heat, and – the much-feared "flashover", this explosive spread of fire, consuming all human life in its path – easy to conjecture, those fleeing and those entering to assist along only bi-longitudinal pathways.

Do we now agree that "inhabited" tunnels, instead of say unstaffed cable or machinery tunnels, particularly those used for transportation and especially road transport tunnels are considered a very high fire risk, often with serious consequences? What do we do about them?

OUR RESPONSES?

If it's an existing installation usually the first task is to assess and reduce risk, using 'Fire Risk Assessment' (FRA) techniques. Mainland Europe provides a good definition, if we're hung up at this stage on the hook of finances – as most projects are, as to what are tolerable and intolerable risks. These are to be found in the ALARP Region, where risks "As Low As Rationally Possible" (ALARP) become acceptable to society. Figure 1 demonstrates. The FRA should identify and carefully examine the dangerous situations/procedures/substances etc. present in the tunnel(s) complex; the activities involving those processes and how they might fail dangerously so as to give rise to fire, explosion and similar events with the potential to harm. Its purpose is to enable tunnel operators to decide what they need to do to eliminate or reduce to as far as is reasonably practicable the safety risks from these dangers. In addition to enhancing 'Life Safety' the FRA and a 'Societal Risk Assessment' can have "added value" benefits – minimizing damage, protecting property and processes, safeguarding the market share, and, one we can all identify with, protecting the environment. Not least "justifying" to one and all the all too important expenditure.

For the new build we can carry out a 'Qualitative Design Review' (QDR) for the proposed tunnel (or those to be altered). During the QDR the scope and objectives of the fire safety design are defined, functional performance criteria established and potential design solutions proposed – usually an acceptable 'fire engineered solution' can be formulated. Using IT we can subsume 'Fire Modelling' and 'Fire Development and Zone Model' techniques to inform judgements. We can also for new and existing tunnels look at 'Human Behaviour within Fire Safety Systems' to bolster fire planning and procedures. The purpose of the QDR being to establish the fire safety issues for the 'workplace' – the tunnel in this case under UK law – the Fire Precautions (Workplace) Regulations 1997 (as amended), and to take account of the appropriate areas within the following main criteria:

1. perform a characterization study of the premises, environment and occupants
2. establish the fire safety objectives
3. establish an evacuation strategy
4. identify acceptance criteria
5. identify fire hazards and possible consequences
6. specify fire scenarios for risk analysis
7. prepare a fire safety manual for use on occupation

then to output these results as a proactive set of sequences to "control" the risks.

FIRE SIZE?

If you are responsible for designing a road or rail tunnel to minimise risk from fire, what features should you include? What objectives should be set? A full response to these issues should consider many questions unrelated to fire, but we are only considering fire here. An elementary issue is the size of fire from which protection is to be provided – the 'fire design size'. There are several approaches to this question, but let us consider only one possibility. Namely to design for the largest fire that may reasonably be foreseen. This hypothesis prevents you "knowingly" designing a tunnel that could become a death trap even when all systems function as well as possible in a foreseeable event. This is a powerful argument and it requires little trumpeting even though there is some difficulty in determining suitable limits to "foreseeable". In practice, it appears commonly interpreted as implying a fire power in the region of 30 MW-100 MW.

Pic courtesy of Securiton AG

STEPS TO BE TAKEN?

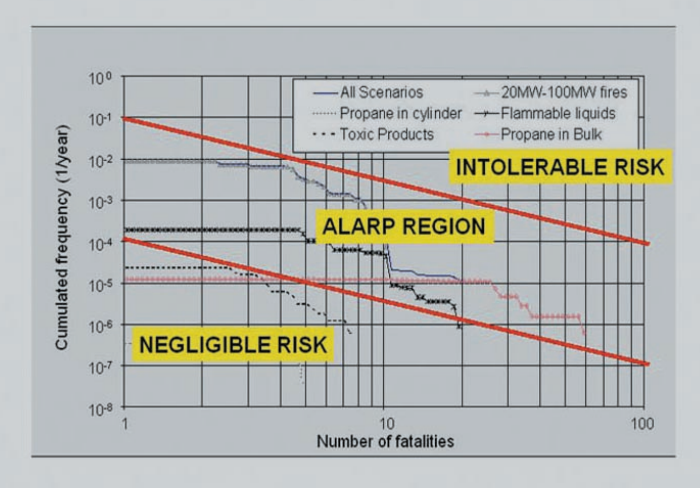
The provision of effective measures against the outbreak of fire is a tremendous challenge. It requires imagination and great expense. The 'Steps to be taken', in the parlance of risk assessment, to perhaps include fire suppression systems at the key risk areas or throughout, a fibre optic cable heat detector based computerised fire warning system or at the least an effective fire warning system, visual monitoring security systems, emergency and primary lighting, signs – emergency, instructional and directional, leaky feeder radio communications, personnel trains or vehicles for emergency logistics support and onsite incident command room(s), powerful ventilation system(s) to control heat/smoke release rates or allow escape, multiple escape route(s) enabling rapid egress or access for first responders. Detailed plans for rapid-response actions by staff will need to be developed and regularly tested and updated. This implies a major commitment of resources and certainly justified in some cases.

FIREFIGHTING MATTERS?

Water, for now, remains the best fire-extinguishing agent. The challenge is extinguishing fires with extremely small amounts of water to enhance efficiency in all directions. Water has such a unique ability to absorb heat – 2,253 Mjoul/sec at 100°C. By creating small water droplets the cooling surface area is larger, more water is in contact with the heat, less water is needed and the fire is extinguished and inerted much faster. Investigations from fires in the above list and others indicate that lessons are to be learnt about fire fighting techniques and equipment, ventilation system controls for fire fighting, good robust communications requirements especially between Regional or National fire brigades, robust water supplies for firefighting, extensive preplanning being vital particularly to ensure sufficient personnel and equipment are provided for the fire attack when its needed.

Ever more innovative and technological appliances appear in the armoury for fire attack utilising small water droplets technology. The Turbo-extinguisher has demonstrated its effectiveness and practical capabilities in many operations of firefighting and controlling clouds of harmful gases. It is an example of a development

Figure 1. ALARP diagram – showing the ALARP region, the economically viable zone that falls between – Negligible Risk and Intolerable Risk.
Pic courtesy of Prof. Hermann Knoflacher, Vienna



from “a theoretical application – to a practical purpose” and can play a part. There are high velocity water Impulse Guns and cannon which can be mounted onboard fire trucks (and helicopters) and as fixed or semi fixed fire-extinguishing installations. There are portable and fixed fire suppression very high-pressure fog guns for firefighters. Together with fixed installation Firefighting Fogging Systems. Both cannon and guns are capable of being used in combination with any water based foam and bio additives to enhance properties where appropriate, making the maximum use of precious water supplies.

LIFE AND LIFETIME FIRE SAFETY?

Life for us is precious and we should use all our human endeavour, patience, attention to detail and environments, and skills shaped on the anvils of bitter experiences at tunnel fires to prevent loss. We have foreseen it now, the unthinkable happens, so we can stop it – this unconscionable roll of tragedies.

Proper measures must be taken, tunnels must be constructed to ensure accessibility for the rescue squads and fire fighters having safe escape routes. The enthusiastic and skilled designers and engineers who develop these systems do not and cannot retain control or involvement over the time-scale of perhaps 100 years or more. They must do their utmost to ensure that the systems they are installing will last. Victims of fire from bad design and constructions cannot be accepted. Systems should ensure a fire would have minimal impact and be attacked at incipient stage, and allow evacuation that offers safe exits from danger. Therefore fire suppression systems should be installed that “guarantee” to increase and sustain – the ‘tenability time limit’ – the period for escape. Firefighting matters!

Research and testing underpins the tremendous effectiveness of fixed installation very high-pressure water fogging systems, this “cutting edge technology”, that has rapid cooling and fire suppression effects, immediately reducing fire and smoke so people escaping and emergency staff responding alike can breath safely. Then one can only conclude that all tunnels should be so provided with these systems?

LONGEVITY?

However impressive, sophisticated or technological the fire safety systems appear at the onset of a tunnel project. Can these same systems continue to work and be available at any time in the life-time of the tunnel? These systems, and the management tasks that support them, must be viewed from this perspective if tunnels are to remain safe for our nations, employees, first responders, transportation of goods, the travelling public and the staff who tend them. That’s the problem question for Tunnels.

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