Wiring Systems for Road and Rail Tunnels

Road, Rail and long Pedestrian tunnels require a significant amount of power to operate safely. Power is usually supplied from the electricity grid but Tunnels have to operate safely even with blackouts, so emergency back-up power is almost always provided in large Tunnel systems. It is not any single system which is most important in tunnel design, rather it is only when all operational and safety systems are working together which can ensure the integrated, reliable and effective operation of life support in both normal and emergency conditions.

Emergency events in tunnels can include any occurrence: Terrorist bombs, gas attacks, earthquake, flooding, collapse or accidents but perhaps the most demanding and likely emergency is fire. Fire has the potential to endanger people even away from the fire source, not because of heat but from the secondary effects of smoke and toxic combustion gases. For this reason Tunnels are designed to manage fires to enable the best possible survivability.

Tunnel safety systems include: Alert systems, Surveillance, Traffic control, Automatic Incident detection, Automatic Smoke Fire and Heat detection, Emergency Communication by Fixed, Telephone, GSM, FM and Loud Speaker systems, Lighting for normal and emergency conditions, Ventilation, Fans, Shutters and Dampers for air quality and Smoke management in normal, evacuation and Fire Fighting modes, Fixed Fire Fighting systems, Pumps & Controls, Barrier systems and others.

It is somewhat obvious but often understated that electrical cables provide the connectivity enabling all this equipment to work and that the reliable performance of the wiring system is directly responsible for the reliable performance of all tunnel operating and safety systems. As such, the wiring system must have an operational integrity equal to or even better than the connected equipment. It must operate reliably for the design life of the tunnel without degradation and under both normal and emergency conditions.

So do we have cables “Fit for Purpose”? The answer is both ‘yes’ and ‘no’ That is: Yes we do have cable systems but No we don’t always use them.
In most parts of Europe, Britain and in many countries around the world, the most common wiring systems used in tunnels for essential Life Safety and Fire Fighting systems are made to pass flame tests which are fundamentally inferior to the fire tests we demand for all other fire rated structures, components and systems. Specifically, common BS and IEC flame integrity tests for Fire Resistant cables only require flame withstand performance for 2 hours or less to 842°C to BS8491:2008 or 930°C to BS8434-2:2003 & 830°C to BS EN50200:2006 or 3 hours at 950°C to IEC 60331 and BS6387:2013 Cat C. All other structures, systems and fire resistant components require fire testing in full scale ovens with temperatures rising well above 1,000°C. So why are fire resistant cables allowed to be tested to different standards and at lower final temperatures?

Interestingly this is not the case in Germany, Australia New Zealand, Belgium and USA/Canada where fire resistant wiring systems are required to meet higher time temperature test protocols according to the Standard Time Temperature Curve: (EN834-1 / BS476pt 20-23 or ASTM E119 in USA) with fire temperatures rising well over 1,000°C for periods up to 2 hours. This is the same time temperature protocol as used for all other structural and fire resistant components.

The Standard Time Temperature Curve was designed and first published in 1918, generally intended for above ground cellulosic buildings and it still forms the basis for fire resistance testing of building structures, systems and components today. It replicates with reasonable accuracy most common fire scenarios in above ground domestic and commercial building environments, however we know well from significant research that fires in tunnels and underground environments can exhibit far more extreme scenarios.

For enclosed environments such as in road, rail, pedestrian tunnels, underground car parks, underground shopping malls, etc. heat generated by fire is often not able to escape as easily as it might in above ground buildings. Smoke and heat build-up can be more rapid and from experience and testing has shown that the resulting fire temperatures can often reach levels well in excess of those experienced in above ground buildings and in far less time. In these cases even the Standard Fire Time Temperature Curve may not be optimal.

In some Road and Rail Tunnels, fire resistance of structures, equipment and systems are required to survive fire Time Temperature environments well above the Standard Time Temperature Curve. Newer test protocols like the Hydrocarbon curve: EN 1363-2, BS476 appendix D, AS/NZS1530pt 4 appendix D., the German RABT-ZTV (car) or (train) or the French HCM (Modified Hydrocarbon Curve) are sometimes used. Contrastingly in most parts of Europe, Britain and in many other countries, the Fire Resistant cable systems employed in tunnels are still often only required to meet the simple and lower temperature British or IEC flame test standards which arguably fall well short of even the Standard Time Temperature Curve protocol.
Such testing has also established that it is unlikely, at any one point in the tunnel, that a cable, structure or a component will experience the extremely high peak fire temperature for much longer than 30 to 40 minutes because in this time most of the fuel at that point will have burnt away. Of course fire spread may move the fire front along the tunnel. The learning from this is that wiring systems used in tunnels and underground environments must be able to withstand very high peak fire temperatures but perhaps for rather less time than we test today.

In USA today, NFPA®502 Standard for Road Tunnels, Bridges, and other Limited Access Highways requires emergency circuit wiring to meet the higher performance of almost 1,350°C but only for 1 hour (Netherlands RWS RijksWaterStaat curve).

So why, when all this essential information is known and published do we often use Fire Resistant wiring systems in Tunnels and underground environments which are only tested to lower standards?

The reason is often that designers rely on the common wiring and electrical standards applicable in each respective country, perhaps not realizing that standards publications are just “minimum” requirements and often only intended for above ground applications. It is left to the designer and Tunnel owner to demand if higher performances are required and sometimes when it comes to electrical wiring systems this is fact is simply overlooked.

Of course some designers route tunnel cables in sand pits or in cable trenches or behind fire resistant tunnel linings. Where this is done the performances may be acceptable due to additional thermal protection but for surface wiring or where cables cannot be protected then appropriate wiring systems must be employed.

Haukur Ingason and Anders Lonnermark of the Swedish National Testing Research Institute presented a paper at the First International Symposium in Prague 2004: Safe & Reliable Tunnels.
Most flexible electric cables are made from hydrocarbon based polymers. Cable jackets are sometimes loaded with flame retardant fillers but often cable insulations are not so these cables may not be fully flame retardant in all situations, especially under overload or short circuit. The high Fire Load of cable insulations, especially polyethylene (even though Halogen Free) poses significant fire risk because PE or XLPE in fire has a very high Heat Release rate, a high oxygen consumption and a high CO and CO₂ outgassing, which contribute to temperature rise, fire spread and asphyxiation risk.

Installing cables in conduit does not solve the problem because decomposition of polymers inside the conduit spreads smoke, toxic and flammable hydrocarbon gasses along the conduits to equipment and distribution boards where any spark such as make or break of circuit breakers, switches or relays can ignite the gasses spreading fire to another location.

One good solution, MICC / MIMS cables uses inorganic magnesium oxide insulation with copper or alloy cable jackets and copper or alloy conductors. These cable designs have no fire load at all so simply cannot propagate fire or add any heat. They produce no smoke, no toxic or flammable gasses at all and can be made to meet any of the higher fire resistance performances for exposed surface wiring. The cable design is in service with London Underground and many other Metro systems worldwide, the cable is 100% water proof, non-aging, with exceptional fire survival performance “as proven and reported after the Anglo/French Channel Tunnel fire in 1996”.

Regrettably many polymeric based Fire Resistive cables are also still used in tunnels today because common electrical cable standards do not always differentiate between applications thus allowing the use of cheap, lower performance cables which often are not designed for, or even “Fit for Purpose” in the more demanding environments of Tunnels.

Excerpts from the conclusion in the Doctoral Thesis of Anders Lonnermark, Department of Fire Safety Engineering Lund Institute of Technology Lund University 2005:

*The rapid increase in temperature and heat release after initial development.. means there is only a short period to begin evacuation.. toxicity calculations corroborate this.. It is a question of minutes.*