Alternative fuels and the future of road tunnels and road tunnel design

Gary Clark
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Introduction

- **TUNNEL DESIGN:** Chief Engineer Tunnel Ventilation Design
- **TUNNEL OPERATION:** Safety Officer for TERN Tunnels in England
- **INDUSTRY:**
  - Member UK Tunnel Design Authority
  - EN Secretary to PIARC Committee
  - Co-lead for PIARC WG4 on Ventilation
  - Member UK Tunnel Operators’ Association
Introduction

Collaborators

- Peter Sturm, University of Graz, Austria
- Norris Harvey, Mott MacDonald, USA
- Matt Bilson, WSP, USA
Introduction

- Why are things changing?
  - Air quality NOx levels / AQM
  - Climate change
  - Technological development
Introduction

- What’s happening?
  - Battery Electrics
    - BEVs in the UK up 51% from 2016 to 2017 (still only 3% incl. hybrid)
  - Private fleets (buses) moving to all-electric?
Introduction

- What’s happening?
  - Hydrogen fuel cells
  - High energy density, good for mid to long range
  - Oxidation process with water as only by-product
Introduction

- Impacts on tunnel safety risk
  - Likelihood of incidents
    - Per vehicle km of new-fuel vehicle
  - Consequences of incidents
    - For tunnel users
    - For firefighters
    - For the tunnel
Battery Electric Vehicles
(Some basics)

- Electric motor powered by battery pack
- Typically liquid-cooled Li-ion
- Fire could be caused by:
  - Damage from collision
  - Short circuit
  - Thermal problems during loading
Battery Electric Vehicles
(Safety Risk)

- Thermal runaway
  - Temp increase and chain reaction one cell after another
  - Oxygen is released within the battery to support combustion
  - Suppression is very difficult

- Toxic gases
  - Breakdown of battery components creates large volume of toxic gases
  - Levels of toxicity may be high – uncertainty still exists
Battery Electric Vehicles (Safety Risk)

Heat Release Rate
- Depends on extent of damage
- Peak not significantly different to traditional?
Battery Electric Vehicles
(Safety Risk)

- Toxics
  - During thermal runaway, flammable and highly toxic gases are released from the battery
  - Acids (eg HF), heavy metals as well as standard combustion products
- Does this change our tenability assessments?
- Are smaller car fires to become more of a concern?
Battery Electric Vehicles
(Safety Risk)

- Extinguishing
  - BEV fires are not easily extinguished
  - Oxidation process continues without supply of external oxygen
  - Cooling is required - research (eg Colella 2016) reported that up to 10m³ of water to cool the batteries in a BEV
  - High risk of re-ignition

- Which of these is a BEV? or hybrid?
Fuel-Cell Powered Vehicles
(Some Basics)

- Fuel cells chemically (oxidation) convert \( \text{H}_2 \) to electric power without burning
- Water is the only emission
- Higher energy density so potential for long ranges
- Fire could be caused by:
  - Damage from collision
  - Thermal problems during loading
- Hazards
  - Fire
  - Explosion
Fuel-Cell Powered Vehicles
(Safety Risk)

- Prevalence
- Vulnerability
  - Hydrogen burns very hot (2000degC)
  - Fuel tank (H₂) if heated will result in a H₂ release and flame (low energy required for ignition)
  - Rupture of tank unlikely?
  - Battery (bigger than conventional EV)
Fuel-Cell Powered Vehicles
(Safety Risk)

- HRR
  - Depends on extent of damage
  - Depends on success of controlled venting
  - Peak not significantly different to traditional?
Fuel-Cell Powered Vehicles
(Safety Risk)

- Toxics – same as BEVs
  - Highly toxic gases are released from the battery
  - Acids (eg HF), heavy metals as well as standard combustion products
- Does this change our tenability assessments?
- Are smaller car fires to become more of a concern?
Discussion points

What are our obligations as tunnel designers, owners and operators?

- Acceptable safety levels
  - As % of vehicles increase, are our safety levels reducing?
- Ensure self rescue is possible from BEV incident, H2 incident, whatever the likelihood?
- Ensure PRMs kept safe until fire service arrival?
Discussion points

We have new Scenarios

- New fire and burning behaviours
- Different toxic gases
- Many uncertainties requiring research
- Should we prohibit these vehicles until we are ready for them?
  - Is this even possible?
Discussion points

New Emergency Response

- Identification of vehicles
- Evaluation of risk (dynamic)
- Emergency plans & procedures
- Will the fire service respond to fires of unknown risk?
Concluding comments

Action is needed

- Priority topic for PIARC TC D5 for the coming cycle
- Subject of interest for ITA-COSUF (workshop planned for 2019)
- Collaboration between PIARC and COSUF agreed
- Research is underway – more is needed
Some references

**ELECTRIC MOBILITY AND ROAD TUNNEL SAFETY**
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**Fire and explosion hazards of alternative fuel vehicles in tunnels**
Ying Zhen Li

**Routes/Roads**
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**Risks associated with alternative fuels in road tunnels and underground garages**
Jonatan Gehander, Peter Karlsson, Lotta Vylund

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**Electric Vehicle Fires**
Francesco Colella1, Hubert Biteau1, Nicolas Ponc Haut1, Kevin Marr1, Vijay Somandepalli1, Quinn Horn1, Richard Thomas Long1
1Exponent, USA

**Challenges of New Energy Vehicles**

B. TRUCHOT and G. MARLAIR
5th Tunnel Safety Officer Forum
Thank you for your attention