Causes of the kaprun disaster

Abbreviations

ALARP	As Low As Reasonably Practicable
BS EN	British Standard European Norm
CCTV	Closed Circuit Television
kV	kiloVolt

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1. Introduction

1. 1. On the 11 th November 2000, the Gletscherbahn Kaprun 2 Funicular in Austria was the scene of a disaster that claimed the lives of 155 people. Only 12 survivors escaped from the scene of the fire.

1. 2. The Kaprun 2 Funicular ran between the Kaprun valley and the Kitzsteinhorn Glacier, safely transporting millions of skiers and tourists since 1974.

1. 3. Kaprun 2 received significant modernisation during 1993 and was hailed as the Pride of Austria’s ski resorts.

2. The Funicular

2. 1. The Funicular was pulled between the Kaprun valley and the reception centre at the Kitzsteinhorn Glacier by a motorized winch and cable system.

2. 2. There were no engines, fuel tanks or drivers; however, the train did have low voltage electrical systems and 160 litre hydraulic reservoir tanks holding hydraulic fluid for the braking system. A conductor operated the hydraulic carriage doors and was located at the front or rear of the train dependent on direction of travel.

3. The Fire

3. 1. An electric fan heater designed for domestic use had been situated in the control console within the rear conductor cab. The electric fan heater overheated and caught fire causing plastic pipework to melt, releasing hydraulic fluid from the braking system.

3. 2. The flammable hydraulic fluid escaping from the melted plastic pipework ignited spreading the fire. The loss of hydraulic fluid also led to a loss of pressure causing the hydraulic braking system to operate bringing the train to a halt approximately 500 metres into the tunnel during its ascent.

3. 3. The fire increased in intensity due to the tunnel acting as a giant chimney which sent toxic fumes, smoke and towards the Alpen centre damaging a 16 kiloVolt (kV) power cable running alongside the track resulting in a total power outage across the resort.

3. 4. The fire claimed the loss of 155 lives through a combination of asphyxiation and burns. The fire increased in its ferocity as a result of an emergency escape door been left open in the Alpen centre following an escape by workers there. The open door increased the chimney effect within the tunnel increasing the intensity of the fire.

4. Reading and Research material

4. 1. There is a limited amount of research material available detailing the Kaprun 2 disaster. Research into the disaster was limited to the end of module brief along with press articles and online videos describing possible events. Press articles and online videos cannot accurately be described as factual.

5. Question 1 – Direct cause of fire and severity

Direct cause of fire

- A design fault caused the electric fan heater to overheat and ignite causing a localised fire in the control console located in the rear conductor cab
- The fire caused by the defective electric fan heater caused plastic pipework to melt resulting in a release of hydraulic fluid
- The hydraulic fluid which was released as a result of plastic pipework melting was flammable
- Released flammable hydraulic fluid ignited and intensified the localised fire causing fire spread
- Tunnel design was a contributing factor to the severity of the fire. The

Severity

- Loss of life
- Burns
- Respiratory injury
- Psychological trauma
- Loss of equipment
- Loss of revenue
- Loss of reputation

tunnel acted as a giant furnace, sucking oxygen in from the bottom and sending toxic fumes, smoke, heat and fire upwards through the tunnel towards the Alpen centre

- Workers left an emergency door open whilst escaping from the Alpen centre. This increased the chimney effect within the tunnel which in turn intensified the fire

6. Question 2 – Direct causes, Potential root causes and Justification

Direct causes	Potential Root causes	Justification
Train • Electric fan heater developed a fault resulting in it	Mindset • Lack of Hazard Identification (scenario resulting in	• The electric fan heater was designed for use in a domestic setting. It

overheating and catching fire

- Overheating electric fan heater caught fire and caused plastic pipework located within the control console to melt releasing hydraulic fluid
- Hydraulic fluid released as a result of melting

fire not identified)

Design

- Poor design process
- Heater design
- Heater location
- Pipework material and location
- Hydraulic fluid (type used in braking system)

Human error

- Complacency

had not been subject to any form of shock test

- No probability of fire recognised at design stage
- Poor design process (no consideration of heater type or location)
- There was a lack of fire detection and suppression systems
- The electric fan heater was fitted into a

plastic pipework was flammable

- Hydraulic fluid ignited

control console close to pipework containing hydraulic fluid

- The use of plastic pipework instead of copper piping could have been as a result of Mindset
- The decision to use plastic pipework for the braking system could have been decided by simple

power to weight calculations (the lower the train weight, the lower the amount of external motive force needed to pull it)

- Cost effective (plastic pipework being cheaper than metal pipework)
- All hydraulic fluids are flammable; however, there are Flame

		Resistant Fluids available. Some variants have an auto-ignition temperature in excess of 400 degrees Celsius
Tunnel • Asphyxiation caused by toxic fumes / smoke • Death as a result of fire burn • Loss of electrical supplies to the resort	• Tunnel design • Lack of Hazard Identification (it was not recognised that a scenario resulting in the production of toxic	• There was no ventilation system used within the tunnel (a semi-transverse system could have been used to remove the toxic fumes /

fumes or smoke could occur within the tunnel) • Lack of Hazard Identification (it was not recognised that a fire could occur within the tunnel as there was a perception that there was fuel or ignition source)	smoke from the tunnel once the fire had started) • No fire detection system • No fixed / portable firefighting equipment located within the tunnel • No emergency refuge areas or escape tunnel • No video surveillance equipment • No emergency action

		signage • No communication equipment • No separation or segregation of supplies (if the 16 kV supply cable had been run through the maintenance tunnel then it's possible that supplies might have been maintained)
Alpen centre • Asphyxiati	• Lack of training	• Open fire exit door

on by toxic fumes and smoke • Lack of visibility	leading to hazard awareness	contributed to the chimney effect within the tunnel • There was no ventilation system use within the Alpen centre (a semi-transverse system could have been used to remove toxic fumes / smoke from the Alpen centre) • No signage indicating fire doors to be kept

closed

- No fire door self-closing mechanism
- Staff training focusing on emergency procedures conducted in conjunction with external emergency services might have highlighted shortcomings

7. Question 3 – Risk reduction measures that may have avoided or reduced the number of casualties

- (A)Use of an approved design heater located away from plastic pipework

- (B)Intercom systems allowing two-way communication between the passenger carriages and the conductor cab
- (C)Internal carriage door override system allowing the passengers to open the doors in the event of an emergency on loss of hydraulic supplies
- (D)Safety Hammers which could have been used to shatter the acrylic carriage windows
- (E)Mobile phone / Wireless network coverage
- (F)Passenger access to portable fire extinguishers
- (G)Signage indicating what to do in the event of an emergency
- (H)Fixed sprinkler systems within the tunnel
- (I)Emergency refuge areas or escape tunnel
- (J)Battery operated emergency lighting
- (K)Fire / Heat detection systems
- (L)Tunnel ventilation system (semi-transverse) which could have been used to remove the toxic fumes / smoke from the tunnel.
- (M)Fixed fire hydrants or Portable fire extinguishers located at set intervals throughout the tunnel
- (N) Training – Staff training combined with external emergency service training
- (O)Segregated electrical power supplies / communication lines (run in the maintenance tunnel instead of alongside the tracks)
- (P)Use of Flame Resistant Hydraulic Fluid
- (Q)Manual fire alarm actuator or Rotary Fire alarm bell located within the passenger carriages

- (R)Closed Circuit Television (CCTV) from the passenger carriages to the conductor cabs

8. Question 4 – Categorisation of Risk reduction measures using the Risk Control Hierarchy model (Step Change in Safety)

- (A)Substitution – Alternative equipment

If a design approved heater had been used and positioned away from the plastic pipes containing hydraulic fluid it's possible the disaster might never have happened.

- (B)Engineering – Additional equipment

If an intercom system had been fitted between the passenger carriages and the conductor cabs then the passengers would have been able to alert the conductor to the emergency.

- (C)Engineering – Modification

If an internal carriage door override system had been fitted then the passengers might have been able to escape from the fumes / smoke and subsequent fire once the train had stopped and it is possible that many of the casualties could have been avoided.

- (D)Recovery – Rescue equipment

A safety hammer would have given the passengers a means of breaking through the acrylic carriage windows.

- (E)Engineering – Modification / Additional equipment

A modification to the train and tunnel could have been made allowing the use of fibre optic cabling / wireless connectivity allowing a phone signal to be used within the tunnel. This would have allowed passengers to contact the emergency services.

- (F)Recovery – Fire extinguishing systems

If the passengers were able to reach the fire extinguishers located within the conductor cab or if portable fire extinguishers were located within the passenger carriages then the fire might have been contained or possibly extinguished at the outset. All public transport must carry accessible fire-fighting equipment.

It’s possible that the operating company were satisfying Fire Safety regulations by carrying portable fire extinguishers; however, it is also possible that the decision to locate these in the conductor cabs was to prevent inadvertent tampering by the public.

- (G)Improve Personnel Awareness – Signage

The use of signage detailing what to do in an emergency might have meant that fewer passengers died. There was a lack of knowledge which resulted in some of the passengers that escaped from the carriages ascending the tunnel; possibly to avoid the heat from the fire at the rear of train being overcome by toxic fumes and smoke which lead to death by asphyxiation.

- (H)Recovery – Fire extinguishing systems

The addition of a fire sprinkler system to the train would probably have been ruled out if an As Low As Reasonably Practicable (ALARP) study had been undertaken as there was a mindset that a fire could not occur i. e. there were no perceived combustibles or ignition sources, secondly the addition of a sprinkler system to the train would have led to a greater spend on the external motive force system used to pull the train as a train sprinkler system would need a reservoir of extinguishing fluid to be stored on the train. However, a fixed sprinkler system located within the tunnel could have prevented a substantial loss of life and subsequent loss of reputation and revenue.

- (I)Segregate / Separate – Barriers / Guards / Shield / Enclosure

If the tunnel had emergency refuge areas or an escape tunnel that had protection from smoke with a heatproof capability then the escaping passengers might have had a better chance at survival. The maintenance tunnel could have been designed or modified to provide this function.

- (J)Engineering – Extra lighting

Battery fed emergency lighting located within the train or tunnel would have helped illuminate any possible escape route. Most battery fed emergency lighting systems can provide escape lighting for approximately 90 minutes.

- (K)Recovery – Detection and Alarms

The use of a fire detection system on either the train or within the tunnel might have alerted the conductor and the operatives at the Alpen centre allowing any emergency escape procedures to be activated.

- (L)Engineering – Local ventilation

A semi-transverse tunnel ventilation system could have been used to remove the toxic fumes / smoke. Some ventilation systems are certified to give a 2-

hour Line of Defence up to 400 degrees Celsius (British Standard European Norm (BS EN) 12101-03: 2015).

- (M)Recovery – Fire extinguishing systems

If the tunnel had fire hydrants or portable fire extinguishers located at intervals along the tunnel, the use of these may have prevented or at least reduced the fire from spreading thereby reducing the loss of life.

- (N)Improve Personnel Awareness – More training / Better instructions / Signage / Drills and Exercises

If there had been a structured training regime which combined staff training with an emergency services response it is possible that a significant loss of life could have been avoided.

The response time for manually releasing the doors by the conductor also contributed to the loss of life as passengers were overcome by toxic fumes and smoke within the confines of the carriages. Similarly the workers that fled the Alpen centre left a fire exit door open which contributed to the chimney effect within the tunnel and increased the intensity of the fire.

- (O)Segregate / Separate – By distance

If the 16 kV power supply cable had been separated by distance from the track then it is possible that the resort supplies and communications to the train may have been preserved. Thought should have been given to routing supplies via the maintenance tunnel.

- (P)Substitute – Alternative substance

If the hydraulic fluid used in the braking system had been a Flame Resistant Hydraulic Fluid then it is possible that auto-ignition of the escaping hydraulic fluid might never have occurred.

- (Q)Recovery – Detection / Alarms

If the carriages had been equipped with manual fire alarm actuators or Rotary fire alarm bells it is possible that the conductor would have been made aware of the incident and passenger panic earlier thereby reducing the loss of life.

- (R)Engineering – Additional equipment

If CCTV had been installed throughout the funicular, this would have allowed the conductor to see the panic that had broken out in the rear carriage and if the camera resolution was high enough it’s possible that the smoke would have been seen.

9. Conclusion

9. 1. The Kaprun 2 disaster was avoidable.

9. 2. The Mindset by the designers and the Kaprun operator that a fire could never happen cost lives.

9. 3. If a thorough Safety Assessment including an ALARP review had been undertaken following the modernisation of the train in 1993 it is possible that the electric fan heater would have been found to be unsuitable for use outside of a domestic environment.

9. 4. It's possible that the company believed that they had complied with all regulatory requirements by placing portable fire extinguishers in the conductor cabs.

9. 5. A lack of training combined with the lack of risk reduction measures as shown above contributed to the loss of life.

9. 6. Twelve passengers survived as a result of one man's prior training and an understanding of what to do in the event of a tunnel fire.

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