THE VENTILATION AND COOLING OF LONG RAILWAY TUNNELS DURING EQUIPMENT: EXPERIENCES AND CHALLENGES ON THE EXAMPLE OF THE GOTTHARD BASE TUNNEL

Samuel Gehrig
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CONTENT AND INTRODUCTION

THE VENTILATION AND COOLING OF LONG RAILWAY TUNNELS DURING EQUIPMENT: EXPERIENCES AND CHALLENGES ON THE EXAMPLE OF THE GOTTTHARD BASE TUNNEL

- Introduction
- The tunnel
- The boundary conditions
- The requirements
- The ventilation system
- The cooling system
- Experiences and challenges
- Conclusion
THE TUNNEL

Multifunction station Sedrun
Ventilation station
Shaft I + Shaft II
Emergency station
Lane change
Cable gallery
Adit Amsteg
Portal Erstfeld

Portal Bodio
Multifunction station Faido
Emergency station
Ventilation station
Adit Faido
Railway tube
Emergency stop in tunnel
Exhaust gallery
Fresh air / escape way

Courtesy of ATG
The equipment work
THE BOUNDARY CONDITIONS AND INTERFACES (2)

The machines deployed

- Diesel engines only, with very strict requirements:
  - EU guideline 2004/26, status June 2004, oxidising catalyst for CO and HC, selective catalytic reduction system for NOx and a particle filter.

- General equipment procedure:
  1. temporary installations, power and communication cables, using tyred vehicles.
  2. slab track (the most power consuming process) using a rail train, a sleeper train, 450 m long concrete carrier train, and several smaller diesel driven machines assisting the trains (e.g. welding machine, concrete shuttles, etc.). Cf. picture.
  3. installation of the remaining systems, such as the catenary, using trains driven with smaller locomotives and rail cars.
THE BOUNDARY CONDITIONS AND INTERFACES (3)

The Heat sources

- Heat sources:
  - Rock: up to 11.0 MWth per tube
  - Machines: up to 1.7 MWth per tube
  - Curing concrete: up to 0.4 MWth per tube
THE REQUIREMENTS TO VENTILATION AND COOLING

- Fresh air quantities compliant to SIA 196:
  - Fresh air for transports: 2 m$^3$/minute, Diesel kW,
  - Fresh air for heavy duty stationary engines: 4 m$^3$/minute, Diesel kW.

- Air velocity in the tubes within a working band of 0.3 m/s to 5 m/s:
  - Consequence: Air volume flow in the tubes limited to 200 m$^3$/s.
  - Corresponding to 6’000 Diesel kW per ventilation line.

- Climatic goal at design: 28°C dry-bulb temperature in the working section

- Climatic goal during operation compliant with SUVA guidelines:
  - No limit on the type of activity up to 28° WBGT.
  - Only light works permitted between 28° to 30° WBGT.
  - No work allowed above 30° WBGT.

- Other requirements:
  - Monitoring of flow, climate and air quality.
  - Re-use of ventilation and cooling systems of previous contractors.
### THE COOLING SYSTEM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cooling GBT north</th>
<th>Cooling GBT south</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. requested refrigeration capacity in tunnel, MW</td>
<td>8.4</td>
<td>11.8</td>
</tr>
<tr>
<td>Max. requested cooling capacity in tunnel, MW</td>
<td>11.4</td>
<td>16.0</td>
</tr>
<tr>
<td>Cooling capacity available at cooling plant, MW</td>
<td>11.4</td>
<td>21.0</td>
</tr>
<tr>
<td>Pump capacity available at cooling plant, m³/h</td>
<td>800</td>
<td>1’120</td>
</tr>
<tr>
<td>Max. number of MACs includable (net refriger. capacity 420 MW each)</td>
<td>20</td>
<td>28</td>
</tr>
</tbody>
</table>

#### Diagram:

- **Erstfeld**
- **Amsteg**
- **MFS Sedrun**
- **MFS Faido**
- **Bodio**

- **north**
- **center**
- **south**
- **west tube**
- **east tube**

- **cooling GBT north**
- **cooling GBT south**

- **cooling water pipes** (feed and return)
- **pump station**
- **heat exchanger**
- **mine air cooler (MAC)**

- **industrial water pipe**
- **cooling plant**
- **pressure exchange system**
EXPERIENCES AND CHALLENGES (1)

High coordination effort
Integration of permanent equipment into temporary ventilation

- Integration of permanent equipment into the temporary ventilation
  - Integrate permanent ventilation elements into the temporary ventilation where available in order to reduce additional maintenance and avoid the installation of parallel temporary systems. E.g. ventilation of cross connections, cf. picture.

- High coordination effort:
  - 45 lots within and outside Transtec, needing at least an interface check to the lot ventilation / cooling
  - 24 lots with interfaces identified.
    Coordination in time and space necessary.
  - Coordination efforts amount to about ½ of total planning time.
EXPERIENCES AND CHALLENGES (2)

Ventilation supports cooling

- Sizing of the ventilation according to SIA 196.
- Monitoring of pollutants’ concentrations during operation.
- Concentrations far below OEL most of the time.
- But: High volume flow rate strongly supports cooling of the tunnel.
EXPERIENCES AND CHALLENGES (3)

Sizing of the cooling
Climatic conditions during transition periods

• Sizing of the cooling:
  – Designed for 28°C dry-bulb temperature, on the assumption of frequent relative humidity at 100%.
  – Operated following the WBGT-index.
  – As tunnel is sealed against water seepage, humidity is low in the central section, about 30% rH.
  – Consequence: Cooling oversized.

• Climatic conditions during transition periods
  – loss of control on the air flows or no cooling available
  – consequence: unavoidable local overheating
EXPERIENCES AND CHALLENGES (4)

Design of cooling water cycle

- Cooling GBT South: open water cycle → high corrosion
- Cooling GBT North: closed water cycle → low corrosion
EXPERIENCES AND CHALLENGES (5)

Alternative cooling concept

Present solution

Future alternative

15-20 °C

1-4 °C

primary cycle

refrigeration plant

above, below ground

n times

water pipes

(feed and return)

refrigerant cycle

air flow

heat exchanger,
condensor, evaporator

cooling plant, open cooling
tower

pump station
compressor
throttle
CONCLUSION

- Past: The systems devised and used fulfilled the requirements and were capable to adapt to an environment with parallel running processes.
- Present: Solid know-how for the ventilation and cooling of long railway tunnels during equipment by experiences made and challenges encountered.
- Future: Brenner Base Tunnel and Lyon-Turin can profit from this know-how.
1) VERT-Filterliste, Geprüfte und erprobte Partikelfilter-Systeme für die Nachrüstung von Dieselmotoren, Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern, Dezember 2005

2) Schweizerischer Ingenieur- und Architekten-Verein, SIA 196, Baulüftung im Untertagebau, Zürich, 1998