General Safety studies and considerations for FCC

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FCC Week 2016
14th April 2016

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Topics

• Status & Overview
• FCC layout used for the studies
• Safety Studies (‘conventional risks’) for FCC
  ➢ Fire Safety
  ➢ Evacuation
  ➢ Air management
  ➢ Cryogenic Safety
• Future studies and contributions
Status & Overview

1. **Smoke extraction concept:**

   - Extraction duct Ø 1.2 m
   - Fixed curtain
   - Roller curtain

2. **Safe Zone:**

   - Dynamic Confinement
   - Length of Smoke Compartment

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Optimisation + new studies
FCC Layout

- For the safety studies, both single and double tunnel solutions are considered:
Safety Studies
Fire risk in safe zones

- Limit the fire risk in the safe zones to absolute minimum (e.g. presence of lighting, signs, transportation)

- For **single tunnel**, equipment with high fire load installed in machine zone or surface (e.g. power transformers, racks)

- A possible solution for **double tunnel**:

See **Radiation Protection**, M. Widorski
If the walking speed (not affected by visibility) is $> v$, occupants can walk away from the smoke front. If it is $< v$ they have to walk in the smoke.
Maximum distance between accesses from machine to safe zone – in standard arc

If Fractional Effective Dose (FED) = 0.3 is targeted (§5.2.1 of ISO 13571), the maximum walking time and distance can be calculated. Results for both configurations (single and double) are reported in the table below.

Main assumptions:

- At $t = 0$ a fire starting next to an escape door;
- Smoke propagates with (conservative) ventilation speed $v = 1.5$ m/s;
- Polyethylene fire grows following an curve (medium) up to 5 MW;
- A minimum walking speed of 0.95 m/s has been assumed.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Single tunnel</th>
<th>Double tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic diameter</td>
<td>m</td>
<td>4.5</td>
<td>Assumed 3.5</td>
</tr>
<tr>
<td><strong>Distance $d$</strong></td>
<td>km</td>
<td>1.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

1 km distance should be considered as baseline for both solutions
Maximum distance between accesses from machine to safe zone – in standard arc

Refined modeling

New additional assumptions:

- **Pre-movement** time (lognormal distribution):
  - detection time, either by people or devices
  - decision making by those in direct vicinity of the fire (e.g. attempts to extinguish it)

- A **walking speed** (uniform distribution) from 0.8 to 1 m/s
Maximum distance between accesses from machine to safe zone – in standard arc

New additional assumptions:

- Adjusted for walking speed reduction due to reduced visibility

<table>
<thead>
<tr>
<th>Ventilation speed [m/s]</th>
<th>Maximum distance (mean value Monte Carlo sim.) [km]*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>1.5</td>
<td>0.73</td>
</tr>
<tr>
<td>2</td>
<td>0.61</td>
</tr>
</tbody>
</table>

*preliminary results

« Underground air speed between 0.7 and 1.4 m/s »

Cooling and ventilation plants, M. Nonis

1 km baseline value validated

Optimisation once ventilation speed is fixed

S. Arias
Tenability limits for FCC occupants

Extract from ISO 13571: tolerable limits of thermal radiation and convection

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Intensity/Temperature</th>
<th>Tolerable time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal radiation</td>
<td>10 kW·m⁻²</td>
<td>Pain after 4 s</td>
</tr>
<tr>
<td>(on skin)</td>
<td>4 kW·m⁻²</td>
<td>Pain after 10 – 20 s</td>
</tr>
<tr>
<td>Convective heat</td>
<td>&lt; 40°C (if H₂O saturated)</td>
<td>&gt; 30 min</td>
</tr>
</tbody>
</table>

CFD modeling of 3D mass and heat transfer allows to compare different tunnel geometries with known tenability limits. Further optimization, e.g. in terms of ventilation, smoke and helium emergency extraction follows.
Evacuation modeling

**Main Assumptions** (based on LHC Long Shutdown 1 studies)

<table>
<thead>
<tr>
<th>Description</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. occupant density in FCC tunnel – same as LHC (4 occ. /100 m)</td>
<td></td>
</tr>
<tr>
<td>Max. occupation in FCC experimental cavern – LHC x 1.5 (~150 occ.)</td>
<td></td>
</tr>
<tr>
<td>Max. occupation in FCC experimental service cavern – LHC x 1.5 (~75 occ.)</td>
<td></td>
</tr>
<tr>
<td>Lift travel time – same as LHC (3 x dist. – 3 x faster)</td>
<td></td>
</tr>
<tr>
<td>Distance between connection to safe zones – 1 km</td>
<td></td>
</tr>
<tr>
<td>Access to machine is denied during beam</td>
<td></td>
</tr>
<tr>
<td>Access to the service cavern is allowed during beam</td>
<td></td>
</tr>
</tbody>
</table>
Evacuation modeling

General concepts on evacuation safety assessment

- Personnel transportation means necessary for evacuation
- Smoke compartmentalization
- Audible alarms
- Light emitting guidance systems to indicate right evacuation direction
- Training of staff

~10 km distance
Evacuation modeling

General requirements for access shafts

• At least 2 distinct evacuation paths are required
• Only 1 access shaft per access point is acceptable
• At least 2 elevators per shaft for redundancy
• Protected staircase may be used as a safe area to reduce elevator ‘lobby area’ – to shelter all occupants
• Stairs may be used as ultimate evacuation mean and access of emergency intervention teams – present assumption, to be studied further
Evacuation modeling

General requirements for access shafts

- Maximum density in safe area (‘lobby area’):
  - 2 people/m² (long waiting times)
  - 3-4 people/m² (nominal scenario)

Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m² for people attending an event in a room without chairs or benches.

S. Arias, S. La Mendola
Evacuation modeling

- In addition to the general requirements to experimental/service caverns:
  - Capacity of the lifts are adapted (more occ. than machine tunnel)
  - At least 2 distinct connections to the access shaft
  - Separate He release path (MCI case) – access to service cavern during beam
  - Access ‘flow’ of personnel is separate from machine (e.g. by floor levels)
Air management

- Provide fresh air during access
- Provide dynamic confinement between “machine zone” and “safe zone” for protection of occupants in nominal and accidental scenarios

Technical solution:
- Air locks and air curtains to maintain $\Delta P$

See Cooling and ventilation plants, M. Nonis
Accidental Helium extraction

- Use smoke extraction system to cope with an accidental He release, during access mode
- FCC Week 2015 – the system’s capacity can cope up to ~1 kg/s release
- Mechanical properties of the ducts/supports can withstand low temperatures?

T. Koettig - ICEC ICMC 2014
Magnetic field in Experimental caverns

- Technical Impact of Magnetic Stray Fields (HSE-DI/fs-FCC/2016-001)
- Stray flux density of 200mT assumed:
  - The hazards are of technical nature:

<table>
<thead>
<tr>
<th>Impact Details of Static Magnetic Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>what</td>
</tr>
<tr>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Transformers (50Hz)</td>
</tr>
<tr>
<td>Transformers (kHz)</td>
</tr>
<tr>
<td>DC motors</td>
</tr>
<tr>
<td>AC squirrel cage motors</td>
</tr>
<tr>
<td>electromagnetic valves</td>
</tr>
<tr>
<td>door latches</td>
</tr>
<tr>
<td>ferromagnetic coils</td>
</tr>
<tr>
<td>vibration</td>
</tr>
<tr>
<td>circuit breakers</td>
</tr>
<tr>
<td>ventilators (fans)</td>
</tr>
<tr>
<td>Instruments</td>
</tr>
<tr>
<td>ferromagnetic structures</td>
</tr>
</tbody>
</table>
Final Remarks

- Limit the fire risk in the safe zones to absolute minimum
- Maximum distance between connection to safe zone: roughly 1 km
- Smoke extraction system capable to extract He gas in case of accidental release during access mode
- At least 2 distinct evacuation paths are required
- 1 shaft with 2 separate elevators and staircase are required per access point
- The hazards due to stray flux density, arising from magnetic fields, in experiments are of technical nature
Further Studies

• Optimisation of smoke extraction following results of tenability limits

• Optimisation of evacuation modeling and new cutting-edge approaches including virtual reality and ascending evacuation experiments

• Studies of automated transportation for occupants – may have impact on the size of the safe zone

• Safety considerations of the proposed electrical network

• Continue safety considerations of the proposed cryogenic installation

• Other studies following the needs and advancement of the FCC study project

Support all FCC WGs on Safety issues
Thank you very much for your attention

Acknowledgements:

C. Cook, S. La Mendola, V. Mertens, M. Nonis, J. Osborne, M. Plagge, R. Trant, M. Widorski
Spare Slides
Maximum admissible crowding in safe zones

Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m² for people attending an event in a room without chairs or benches.

These figures have been tested for a number of fire scenarios.
Maximum distance between accesses from machine to safe zone – in standard arc
He Spill test – temperatures @ ceiling level

~ -40°C

~ -80°C

T. Koettig - ICEC ICMC 2014
Walking speed as a function of age

Source: www.wpi.edu