OVERVIEW OF SAFETY SYSTEMS AND EVACUATION STUDY IN THE FCC TUNNEL

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on behalf of the Safety WP team
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OVERVIEW OF THE MAIN SAFETY FEATURES AND ADVANCEMENTS
Ventilation & Emergency extraction

Objective:

- Safe egress:
  - Maintain tenability conditions for occupants
  - Evacuation path free of toxic fumes (inhalation and visibility)
  - Dynamic confinement (prevent smoke propagation)

Baseline:

- Detection 120s
- > 7000 m$^3$/h per compartment (up to 10 000 per compartment)
- Extraction system less then 60s to ramp up

Up to 10 000 m$^3$/h / compartment

Schematic of the ventilation system in a compartment

Studies for the effect on Helium extraction on-going

O. Rios et al
"Fire safety assessment for FCC - PBD study for FCC and HE-LHC", FCC Week 2018

Baseline:

- Detection 120s
- > 7000m$^3$/h per compartment (up to 10 000 per compartment)
- Extraction system less then 60s to ramp up
Fire compartments

Objectives:
• Safe egress:
  • Static confinement (prevent fire/smoke propagation)
  • Dynamic confinement (prevent fire/smoke propagation)
  • Increase possible waiting time for emergency vehicle
• Search & Rescue from Fire Brigade
  • Enables better operational tactics
  • Reduces the smoke diving (air supply)
• Reduces asset loss
  • Limits the propagation and damage to the accelerator and equipment

Baseline modification:
Compartment length = 400 m
(440 in CDR)

Fire compartments:
• 28 / sector

Alcoves:
• 5 + 2 / sector
Safety systems

Objectives:

• Safe egress
  • Automatic trigger of safety-related actions
• Notification of emergency teams
  • Signal to the Safety Control Centre

Main Safety Systems & Instrumentation:

• Compartment doors
• Fire (smoke) detection
• Smoke extraction dampers interface
• Call points
• Evacuation Signalization
• Access sectorization door(s), patrol boxes
• Occupancy tracking / logging per sector

Other FCC-tailored options are under investigation – R&D
Product Breakdown structure

Objectives:

• Provide the most accurate cost-estimate

Process:

Layout of the access points (underground and surface) → Category of Safety-related equipment → Inventory per point & per safety system → Cost estimation

• Access doors;
• Fire detection;
• Sirens;
• Rad monitors;
• ODH detectors;
• …
SAFETY STUDIES
Evacuation study

Aim

- Define the surface of the safe areas at the bottom of the shaft (protected area waiting for the lift to evacuate to the surface)
  - Maximum number of simultaneous occupants allowed per sector
  - Longest evacuation time(s)
  - Optimal personnel transportation during emergency

Scope

- Study emergency situations:
  - During operation: Long shutdown
  - Occupants are working in the tunnel

Note: Second step is to perform the same study for Installation phase of the FCC-ee machine
Evacuation study

Model

• Worst case scenario: fire in the vicinity of Shaft B towards Shaft A
  → Occupants in sector A-B obliged to evacuate through Shaft A
  → Occupants in the neighboring ½ sector will also evacuate through Shaft A
  → Alcoves are distributed along the tunnel (A1 – A7; C1 – C4)
  → Occupants are randomly distributed along the tunnel, in groups
  → Occupants each have a personal transportation mean to evacuate, located in the nearest alcoves
  → Evacuation alarm sounds:
    Pre-movement
    Occupants walk to the nearest alcove, then transported to Shaft A
    Wait for the lift to be evacuated to the surface
  → Traffic disturbance neglected
  → Probabilistic model: plain Monte-Carlo simulations with set of random variables:
    Occupant distribution; walking speed; transportation speed
    Sample size: 1000
Evacuation study

Boundary conditions

• Occupancy:
  → Limited by the transportation means (each occ. has a vehicle to evacuate)
    Vehicle capacity:
      ❑ Scenario 1: 2 occ. / vehicle
      ❑ Scenario 2: 3 occ. / vehicle
  → Limited by the parking space (alcoves and shaft)
    Parking space:
      ❑ Alcoves: 10
      ❑ Shaft: 20
  → Total occupants:
    ❑ Scenario 1: 260 occ. → 174 occ. / sector
    ❑ Scenario 2: 390 occ. → 260 occ. / sector

• Spatial distribution of the occupants:
  → Homogeneous (linear) occupancy will not result in possible overcrowding over time + doesn’t reflect reality
  → Total occupancy is randomly distributed
    ❑ In groups (2 – 10 occ.) along the 1.5 sector model
    ❑ Normally distributed (binominal-type approach)
    ❑ Relevant for the ‘crowding’ phenomena in the safe area
  → Each run will yield a different occupancy distribution
    (x groups of y occupants spread randomly along the tunnel)
  → Monte-Carlo sampling

LHC data: Max. 49 occ/sector (LS2) – 95% CI (T. Otto – EDMS N.2851367)
Scaling factor of 3: ~150 occ/sector (Scenario 1: 15% ↑; Scenario 2: 70% ↑)
Evacuation study

Results

Occupant distribution in the tunnel:

Probabilistic approach:
- 2000 – 4000 different group of occupants
  (2 – 10) spread in the 1 ½ sector

Other metrics:
- Maximum avg. evacuation time
- Occupancy density in the first 20 min
- Effect of vehicle type
- 

*LHC Safe area ~21 m²
Evacuation study

Results – Scenario 1 (174 occ / sector – 260 total)

Occupant distribution in the tunnel:

Result of 50 MCS (1000 samples each)

Occuapnt density in the safe area

Safe area size of 40 m² acceptable!

No specific overcrowding
Evacuation study

Results – Scenario 2 (260 occ / sector – 390 total)

Occupant distribution in the tunnel:

Result of 50 MCS (1000 samples each)

Occupant density in the safe area

Not acceptable
Tolerable
Safe area: 40 m²

Safe area size of 40 m² not suitable!
Overcrowding observed at ~ 20 – 25 min
Optimal size?
Evacuation study

Results – Maximum crowding

The results show that having a safe area of 50 m² would be suitable in both scenarios, within a 95% confidence level.

Next steps

Use the model for other access modes:
- During machine installation
- During degraded modes

Improve the code to cope with other studies:
- Fire Brigade intervention in case of ‘Search & Rescue’
- Results to feed into other studies (e.g. fire/smoke simulations)
### Cryogen release – numerical simulations

**Aim:**
- **Simulate a Helium leak in the vicinity of the SRF cryomodules**
  - None-stay zones
  - Pressure build-up in a compartment
  - Access conditions when cold

**Boundary conditions:**
- **Species transport CFD:**
  - Helium & air
  - Mixture of chemical species
- **Adiabatic (for now)**
- **SST (k-ω) turbulence model**
- **Simulate a compartment in the RF sector – simplified geometry**
- **Air inlet = 4 * 510 m³/h (diffusers)**
- **Longitudinal air velocity ~1 m/s**
- **Helium spill: 3.5 kg/s @ 5 K**
- **Rupture disk: 50 mm Ø**
- **Helium inventory: still tbd**

**Preliminary results**

In a few seconds (4 – 10s) the O₂ levels reach limit at the evac path and for several meters.
Fire Detection

Aspirating Smoke Detection (ASD) limitations:

- Technical: distance of aspiration tubes (M. Dole et al, "Long Distance Aspirating Smoke Detection for Large Radioactive Areas")
- Integration: number of tubes

  SPS example:
  - 4 x 110m tube per compartment, giving ~15 tubes/alcove, 1-2 tubes/ASD
  - 1 CIE (central) of Fire Detection / alcove

<table>
<thead>
<tr>
<th></th>
<th>Per alcove</th>
<th>Per LSS/ARC</th>
<th>Total</th>
</tr>
</thead>
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<tr>
<td>Detection locations</td>
<td>8 in arc + 2 in alcove</td>
<td>70</td>
<td>560</td>
</tr>
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<td>Aspiration tubes</td>
<td>6.8 km</td>
<td>47.6 km</td>
<td>380.8 km</td>
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<tr>
<td>Fire detection central</td>
<td>1</td>
<td>14</td>
<td>56</td>
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<tr>
<td>Monitoring system</td>
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</table>

- The systems today in place in other accelerators meet the basic requirements. However, the technology is reaching its limits and not all solutions scale well for the FCC.
- Study generalized vs localized fire detection?

Further R&D is required
Outlook

Ongoing studies / main focus for MTR:

- Complete the PBS (cost estimate)
- Complete the cryogenic release simulations
- Perform fire simulations in the Klystron gallery
- Perform the evacuation study during installation phase
- Use the FCC mock-up to integrate real scale safety systems

Acknowledgements to the co-authors (Safety WP) and to the colleagues from the TIWG pillar for their contributions

FCC Safety WG is happy to receive ideas and have colleagues to join the effort
Thank you for your attention
SPARE SLIDES
Evacuation study - Fixed Conditions

Shaft parameters:
- Area: 40 m²
- Capacity of the Lift: 76 (2 lift * 38 person)
- Lift speed: 4 m/s
- Height of the shaft: 400 m
- Un/Loading time of the lift: 50 s

Occupant parameters:
- Occ. Walking speed: Normal distribution 1.2(0.3) m/s, Sample Size 1000
- Occ. Transport velocity: Uniform distribution [20,30] km/h, Sample Size 1000
- Occ. Numbers for each group: Binomial Dist. (Max 10, Min 2, 3 Standard Deviations, Sample Size 1000)
- Occ. Premovement time: 180 s

Group parameters:
- Group positions: Binomial Dist. (Max 11400, Min -5503, 3 Std. Deviations, Sample Size 1000)
Evacuation study - Boundary Conditions

Number of studies: 2

For each study:

Number of runs for each study: 50

For each run:

Distribution of the group positions inside the tunnel, number of occupants in each group and the total group number randomly change

Group parameters:

- Group positions: Randomly picking from the sample
- Number of Groups: Until sum of the occupant numbers in the groups is equal to Total Occupant Number
- Occ. Numbers for each group: Randomly picking from the sample

Number of simulations for each run: 1000

For each simulation:

- Occ. Walking speed: Randomly picking from the sample
- Occ. Transport velocity: Randomly picking from the sample
Evacuation study

FCC Evacuation Study

Transport Occ. Capacity [#2]

2 Cases
For each Occupant Capacity of the Transport Vehicle

Transport Occ. Capacity [#3]

50 Runs with Different Occupant Distribution in the Sector
For each case

1000 Simulations with Different occupant walking speed and Occupant transport mean velocity
For each run
Cryogen release – numerical simulations

$O_2$ levels (%)  

Temperature (K)