Controlled Cold Helium Spill Test in the LHC Tunnel at CERN

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Content

- Situation of safety measures in the LHC tunnel related to ODH
- Requested parameters of the helium spill
- Experimental set-up in the LHC tunnel
- Measurement results along the tunnel
  - Movies in up- and downstream direction
  - Temperature
  - Oxygen content (ultrasonic and chemical sensors)
  - Tunnel air velocity and propagation speed of helium air mixture
- Conclusions
Helium Spill Test in LHC Tunnel – Current Situation

Confined space
Specific access rules
PPE

He spill test location
Helium Spill Test in LHC Tunnel – Cross section

LHC tunnel lay-out (including jumper)
After discussion (HSE) and Departmental Safety Officer (DSO):

No stay zone of 3 m, centered around release point.

LHC Project Report 684*: Header C
  Average flow 1 kg/s
  Length of helium jam 6 m

4.6 K & 0.36 MPa supply line

*SUMMARY OF THE EXPERIMENTAL STUDIES OF COLD HELIUM PROPAGATION ALONG A SCALE MODEL OF THE LHC TUNNEL
Helium Spill Test in LHC Tunnel – Proposed Updates

Scale model tests and several simulations have been performed.

Two different proposals are in place.
Enormous difference between proposal based on scale model and proposal based on simulation work

Perform a representative He spill test in the tunnel to check the validity of the different models and calculations and base new access rules on these validated calculations:

- Mass flow rate of the helium spill: 1 kg/s, 0.35 kg/s and 0.1 kg/s
- Total mass spilled per test: 125 kg (= 1000 liter LHe)
- Ventilation in “tunnel access speed”: 18000 m³/h, equiv. to 0.7 m/s
Pressurizing 2 Dewars with warm helium gas from gas cylinders at 150 m distance. The liquid mass flow will be measured by scales on which each Dewar is placed.

Dewar:
- Design pressure: 2 bar
- Primary safety valve: 0.5 bar
- Pressure drop system: 0.1 bar

Helium Spill Test in LHC Tunnel – Experimental Set-up
Helium Spill Test in LHC Tunnel – Experimental Set-up

Tunnel side view

Tunnel cross section

Two 500 l Dewars with liquid helium combined extraction system

Dewars placed in the walk way Release mock-up on top of magnet
#### Helium Spill Test in LHC Tunnel – Instrumentation

- **Equipment in the tunnel with measurement system**
  - 25 Temperature sensors (Pt100)
  - 25 ODH (special development of fast reacting measurement head)
  - 3 ODH chemical type => GS Oxygen Sensor KE 25
  - 6 video cameras
  - 4 air velocity measurement stands
  - 2 scales (used for calculation of mass flow)

- **Equipment was placed on 15 stands:**
  - 8 downstream (over 200 meter) and
  - 7 upstream (over 100 meter) of air ventilation direction,
  - Spill point location as reference 0 m.

- **ODH Sensors are placed at 0.5 m, 1.75 m height in passage area.**

- **Temperature sensors are also placed close to the ceiling.**
Helium Spill Test in LHC Tunnel – Set-up

Measured values:

- At spill location
- Upstream direction
- Downstream direction
Spill test set-up

Spill point with temperature sensors (at spill point and at 50 cm). Magnet vacuum vessel protected by Armaflex.

Helium dewars in place connected to the spill point. Dewars are pressurized by warm helium gas.

No persons were present in the tunnel during the test.

Test stand with ODH and temperature sensors at three levels. Also temperature sensors at top of tunnel.
Temperature of the released helium approaches 4.2 K after ~ 25 sec.

All personal O₂ deficiency detectors triggered including farthest one @ 200 m distance and 0.3 m height
Some results of the 1 kg/s spill

In contrast:
No change in temperature detected at 1.75 m and 0.5 m height
“Visual” results 0.1 kg/s spill @ T=20-25 K

View + 23.7 m

Spill of 0.1 kg/s
Comparison of result for different mass flows

O₂ concentration at 30 m downstream

O₂ concentration (%)

Time in min

# +30m_S_50cm@1kg/s
# +30m_S_50cm@0.1kg/s
# +30m_S_50cm@0.34kg/s
Comparison of result for different mass flows

O₂ concentration at 100 m downstream

- # +100m_S_175cm@1kg/s
- # +100m_S_175cm@0.1kg/s
- # +100m_S_175cm@0.34kg/s
Simulated vs lowest measured O₂ concentration downstream

Tunnel O₂ concentration when fully mixed air and helium spill (practically independent of helium spill-temperature)

Simulation – 0-dim model:
- Zero dimensional model considering:
  - Only downstream flow, 100% of helium in that direction
  - Full adiabatic mixing of air and helium
  - Incompressible flow
  - No heat exchange with tunnel surface or magnet string
Results 0.1 kg/s spill test

- No noticeable lowering of temperature (T < 10 K) below 1.75 meter height anywhere in the downstream direction. At tunnel ceiling height => temperature lowers by about 40 K.

- No noticeable lowering of the ODH level (< 1%) at 20 meter or further downstream of the spill point and below 1.75 meter height.

- Even at 10 meter downstream of the spill point and below 0.5 meter height no noticeable lowering of the oxygen (< 1%) content has been measured.

- No noticeable lowering of the temperature or the oxygen content in the upstream direction.

- No visual obstruction at any distance from the spill point and below 1.75 meter.

Result of the He spill test

No access to the LHC tunnel:
- during transient conditions
- when magnets are energized

Maximum estimated He spill < 0.1 kg/s
Consequences of spill tests

After the results of the spill test became available, a working group has been studying the implementation of these results in the LHC tunnel access procedures.

Estimate MCIs which can create these spill flows:

1) Spill of 1 kg/s corresponds to the MCI:
   • during pressure test of “cryogenic infrastructure”
   • during cool-down from 300 K to 80 K
   • when there is a current of 1 kA in one of the magnet systems (stored energy about 100 kJ);

2) Spill of 0.32 kg/s corresponds to the MCI:
   • during phase 1 of powering (max 30 kJ in circuit)
   • special test conditions

3) Spill of 0.1 kg/s corresponds to the MCI:
   • human mistake when the magnet system is not powered
Consequences of spill tests

Seen the analysis of the MCIs for the different conditions of the LHC, and seen the result of the different spill tests made, this working group recommended:

1. For pressure test: no access to arc of the LHC tunnel under test and to the upstream and downstream half-Long Straight Sections
2. No access to arc being in cool-down between 300 K and 80 K, and special access rules for adjacent areas;
3. Phase one of powering: use controlled instrumentation whenever possible, only access possible for powering experts;
4. Long Straight Sections: no recommendations
5. Special areas (stand alone magnets, cryo-feed boxes, cryolines) T<80 K: prior authorization needed for work in vicinity of these areas. Personal ODH needed;
6. Inner Triplets (no alternative escape route) are forbidden zones. Only access under very exceptional circumstances, work-plan must be submitted beforehand for approval (only access if “vacuum pressure is followed locally by second person”, or if the helium in the IT is emptied beforehand.
7. For interventions in the arc area (below 80K) personal ODH needed, number of persons in this area shall be limited; work declaration needed beforehand.