Safety Consolidation in and around the Injector chain*

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On behalf of
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T Otto & the PS Radiation Working Group (PSRWG)
P Bonnal (Risk analysis procedures)

* Safety Consolidation at the PS
Safety Consolidation at the PS

“Some bloke wants to know if we’ve carried out a thorough risk assessment?”
Safety Consolidation at the PS

• In view of the decision to keep the PS as LHC Injector for 25 years*
• PS Safety review (F Szoncso)
  – Snapshot of the situation today
  – Aiming to identify Hazards
• Risk analysis (P Bonnal)
  – Establish a prioritized action list for risks identified by the PS Safety Review
• Input from the PS Radiation Working Group (T Otto)
  – Evaluation of beam intensities and loss rates
  – Identification of main radiation hazards
  – Impact on operations & tunnel interventions
  – Recommendations

* Decided after Chamonix 2010
PS Safety review

- Mandated by S Myers & R Trant to:
  - ‘establish the facts related to the safety of the CERN PS and assess the safety compliance of the PS in view of its long-term operation as LHC injector’

- Members: EN/MEF, HSE, BE/OP, TSO

- Aim to identify hazards whilst avoiding any prejudgment
  - Groups involved in the operation, maintenance, modification and emergency handling at the PS were contacted individually
  - Standard questionnaire plus specialized questions
  - Report the situation as it is today (as seen by those intervening in the tunnel)

- The results can be found in the CERN Proton Synchrotron Safety Review
  - [https://edms.cern.ch/document/1119511/1](https://edms.cern.ch/document/1119511/1)
PS Safety Review: Teams contacted

- Civil Engineering, buildings, tunnel structures
- Services: Tunnel cooling and ventilation, Electricity, Cabling, Transport
- Beam related equipment: Vacuum, RF, Beam instrumentation, Kickers & Septa, Magnets
- Safety systems: Interlocks, Access and Safety systems, Fire Brigade, Environment
- Shutdown Coordination
PS Safety Review: Hazards identified 1/2

- 41 potential hazards identified including...
  - Asbestos pipe insulation
  - Safety communication for personnel intervening in the tunnel (CERN and external contractors)
  - Leakage of air from the tunnel, smoke extraction system has no filter, problems to maintain constant pressure differentials in the tunnels
  - Possibility of corrosive smoke in case of fire (cables, batteries...)
  - No flooding warning interlock in presence of pressurized water systems
  - HV is present on ion pumps permanently (during access)
  - Many of the procedures for testing magnets and other elements rely on expert knowledge and not written instructions
PS Safety Review: Hazards indentified 2/2

- Cable deterioration due to radiation, overfilled cable trays & unidentified cables
- Lack of building/tunnel maintenance (leaks, water infiltrations)
- Some walkways and stairs are unsuitable and difficult to use
- Tunnel concrete floor slabs damaged
- The AUG layouts and the action of individual buttons are not clear
- Few systems have individual emergency stop buttons (not coherent approach)
- Lack of safety exercises and evacuation drills
- Radiation issues are covered by the PSRWG
Prioritizing risk mitigation measures

« PS Safety Review » of Feb. 2011

Prioritized list of risk mitigation measures

Possible measures that will most improve outstanding safety issues → Top of the list

Risk Mitigating actions

Actions that are to be taken within budgetary limits
Evaluation and analysis phase

- **Identify** all safety risks from the hazards listed in the *PS Safety Review Report*

- **Evaluate** those risks from to 2 perspectives:
  - **Probability** of occurrence
  - **Impact** on health, safety and environment

- **Analyze** those risks:
  - List the *existing mitigation measures* (already in place):
    - Preventive measures (↘ probability)
    - Protective measures (↘ impact)
  - List possible *additional mitigation measures*
  - Estimate their feasibility (cost, manpower, schedule...).
Evaluation and analysis phase

- Review existing mitigation measures, i.e. those already in place
  (risks are weighed taking these measures into account)
  **1st ranking (before new measures are implemented)**
  sorting = from highest risk to lowest risk
- Identify additional mitigation measures
  (incl. their cost estimate, the manpower required, their feasibility from a schedule point of view...)
  Risks are then re-weighed considering the implementation of these additional mitigation measures
  **2nd ranking (after new measures are implemented)**
  sorting = from highest risk improvement to lowest.
The PSRWG evaluated beam intensities and loss rates for 2010 operation of the PS. This allowed a correlation between beam loss and the observed radiation hazards.

<table>
<thead>
<tr>
<th></th>
<th>Intensity</th>
<th>Relative Loss</th>
<th>Loss rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>$8.2 \times 10^{12} \text{ s}^{-1}$</td>
<td>6 %</td>
<td>$5 \times 10^{11} \text{ s}^{-1}$</td>
</tr>
<tr>
<td>Extraction (high.int. beams)</td>
<td>$6.4 \times 10^{12} \text{ s}^{-1}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td></td>
<td>10 %</td>
<td>$6.4 \times 10^{11} \text{ s}^{-1}$</td>
</tr>
<tr>
<td>MTE</td>
<td></td>
<td>1 – 2 %</td>
<td>Up to $1.3 \times 10^{11} \text{ s}^{-1}$</td>
</tr>
</tbody>
</table>

Not including nTOF, LHC, EAST HALL.
<table>
<thead>
<tr>
<th>Hazard</th>
<th>Main Locations</th>
<th>Concern</th>
<th>Mitigation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air activation</td>
<td>Whole PS, numerous pathways</td>
<td>Release to environment, radiation dose to workers and public</td>
<td>Assessment to demonstrate negligibility</td>
</tr>
<tr>
<td>Stray radiation</td>
<td>Route Goward Downstream of South-hall</td>
<td>External irradiation of personnel on-site and of public</td>
<td>Shielding</td>
</tr>
<tr>
<td>Activation of material in the tunnel</td>
<td>SMH16 (MTE) Downstream SEH31 (CT)</td>
<td>External irradiation of workers during access</td>
<td>Allow decay time</td>
</tr>
</tbody>
</table>

* other than reduction of beam loss

Not measured today
Activation: Ambient dose rates **limit** the possibility for urgent interventions

E.g. Replacement of SMH16

14 days after accelerator stop: $H^*(10) \approx 20 \text{ mSv h}^{-1}$

↓

Septum exchange possible without breaking internal RP rules

Solutions:
- Hardware upgrade to allow remote handling
- Wait longer (unrealistic due to logarithmic decay characteristics)
- Reduce and/or **constrain beam loss**
PSRWG Recommendations (1)

• Air activation
  – Cost an upgrade of ventilation allowing proper assessment of releases, in terms of CHF and of person-mSv
  – Take an informed decision

• Stray Radiation
  – Homogenise radiation shielding on top of PS, allowing for probable intensity upgrades: Linac 4 and 2 GeV PS Booster at full capacity
  – +180 cm earth downstream of South-Hall
  – +180 cm concrete on Route Goward
PSWRG Recommendations (2)

• Accelerator Activation
  – Reduce loss focalized on SMH16 by various means (dummy septum, barrier buckets, ...)
  
  – Introduce a beam loss constraint for routine operation:
    • $< 10^{10}$ s$^{-1}$ at any location (without septa)
    • $< 10^{11}$ s$^{-1}$ at septa
    • $< 10^{12}$ s$^{-1}$ overall

  – These constraints allow major interventions after a breakdown (magnet or septum exchange) with 14 days decay time
Actions for the future

• Hazards identified in the PS Safety review
  – Risk analysis to assess the hazards identified and produce a set of prioritized actions
  – Implement inside an Injector Consolidation program?

• PSRWG
  – Modify ventilation system to allow measurement of air activation
  – Additional shielding requirements identified
  – Remote handling for certain elements?
  – Reduce localized losses with “technical or beam” solutions
  – Use a beam loss constraint rather than an extracted intensity limit
Questions asked 1/3

• Do you believe that your equipment is operationally safe today?
• What risk does your equipment pose for the safe operation of the PS?
• Does your equipment pose any safety issue to other personnel?
• Do you believe your equipment will degrade in terms of safety and will require replacing or even redesigning?
• How could your equipment be improved to make it safer than it is today?
• When making interventions on your equipment, do you consider the procedures you follow today are safe?
• To make your interventions safer, what procedures should be improved?
Questions asked 2/3

• Do you consider the PS tunnel to be a safe working environment?
• What elements of the tunnel do you consider to be either unsafe or a potential risk to your health and safety?
• Do you consider any other PS hardware to be unsafe?
• Are you aware of any environmental issue in the PS that should be addressed?
• Are you and your team fully aware of the emergency equipment and procedures while working in the tunnel?
  – Emergency exits?
  – Emergency lighting?
  – Emergency phones and numbers?
  – Emergency stop buttons (AUG)?
  – Fire fighting equipment? Extinguishers, what type and how to use them?
Questions asked 3/3

• Specific questions....
  – Can beam losses affect your equipment?
  – Does induced radio-activity affect interventions on your equipment?
  – Is your equipment protected by specific interlocks?
  – Do you use/store dangerous chemicals/materials
  – Do you have dangerous systems which must remain on during a shutdown period?
  – Is the tunnel equipped with smoke extractions systems?
  – Do your equipment present a particular fire risk?
  – How is the AUG system laid out?
  – ..................