Evian 2017 workshop

LHC-TDE dump block
2017 operational review and outlook for 2018

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Outline

1. 2017 operational report and feedbacks
2. Graphite oxidation studies and consequences
3. Outlook for YETS and 2018 operation
4. Conclusions
2017 operational report
Current status

- UD62 dump block showed a significant leak (not clearly identified location – possibly around the downstream window)
  - Core current at atmospheric pressure
- UD68 small leak downstream window
  - UD68 core at nominal overpressure and no leak evolution in 2017 with respect to 2016
- $\text{N}_2$ atmosphere still guaranteed in both dumps
  - Access to tunnel still necessary to exchange $\text{N}_2$ bottles
  - Preference to run with $\text{N}_2$ to avoid any possible core oxidation in presence of air in high temperature regions
Dump block configuration

- 700mm High Density Graphite
- 3420mm Flexible Graphite
- 5x 700mm High Density Graphite
- Diameter: 690mm
- Stainless Steel Uranus 45 (SS 318LN)
- Upstream Window
- Downstream Window
- Dump block assembly
- Beam
- 10mm Titanium Grade 2
- Stainless Steel Uranus 45 (SS 318LN)
Dump core inside shielding
Nitrogen sector
UHV-to-N2 window
Dump cooling system
Spare core DS window
Spare dump core
Spare US opening to graphite
Reminder of past observations (2015)

- November 2015:
  - Leak in the UD62 (5-10 mbar*l/s), fixed by tightening flanges close to the dump
  - Operation ok in 2016
Reminder of past observations (2016)

- April 2016:
  - Leak appeared in UD68, confirmed by 1000bulles, in the flange downstream the C/C window
  - Fixed during EYETS16-17
  - ~2-3 mbar*l/s
2017 observations

- During mid August 2017, following a series of high intensity dumps (following the 16L2 issue), the UD62 dump developed (again) a major nitrogen leak

- $>> 10 \text{ mbar} \cdot \text{l/s}$
N$_2$ leaks consequence

- Original worry (triggered by the LHC TDR) was that graphite exposition in air would have trigged a “significant damage”
- Therefore conservative decision (w/ MPP) to maintain – at all times – a nitrogen atmosphere inside the dump core
- Studies executed in 2017 indicated that the risk of massive oxidation (at least for the current operational scenario) can be excluded (details later)
2017 observations

- Bottle racks exchanged several times in order to guarantee $\text{N}_2$ flow in the UD62 dump
- In all case, bottle exchange has been a preventive measure, without a real operational risk
- Most intervention executed in the shadow of other activities
  - Could have become several tens of hours cumulative “downtime” if required to be executed exclusively
Intervention during TS2

- In order to identify the possible leak location, robotic inspection performed on the UD62 dump block downstream window during TS2.

- Despite the significant amount of effort, the leak was not identified (dump was NOT under vacuum).
Graphite oxidation studies (2017)
Temperature rise

- Temperature rise defined by beam sweep
- Nearly linear with bunch intensity
- Small variation with number of bunches (2508 is ~same of 2750-2808)
Expected temperature TDE rise

Bunch intensity: $1.2 \times 10^{11}$ protons
Emittance: 1.4 murad (peak temperatures in the TDE show only weak dependency on transverse bunch emittance because sweeps dilution dominates)

<table>
<thead>
<tr>
<th>Number of bunches</th>
<th>Max. temperature at side in contact with $N_2$</th>
<th>Max. temperature in low-density core</th>
<th>Max. temperature at side in contact with $N_2$</th>
<th>Max. temperature in low-density core</th>
</tr>
</thead>
<tbody>
<tr>
<td>2556</td>
<td>990 °C</td>
<td>780 °C</td>
<td>1480 °C</td>
<td>1140 °C</td>
</tr>
<tr>
<td>1916 (8b4e)</td>
<td>770 °C</td>
<td>610 °C</td>
<td>1160 °C</td>
<td>900 °C</td>
</tr>
<tr>
<td>1868 (8b4e)</td>
<td>760 °C</td>
<td>600 °C</td>
<td>1140 °C</td>
<td>880 °C</td>
</tr>
<tr>
<td>1836 (8b4e)</td>
<td>750 °C</td>
<td>600 °C</td>
<td>1110 °C</td>
<td>860 °C</td>
</tr>
</tbody>
</table>

Peak temperature depends on how many empty buckets one has in the slow part of the sweep

- If gaps between train changes then minor change in the high-T regions
- If filling scheme changes, then minor change in the high-T regions
Graphite tests at high T

1. Laser impact in air (CERN)
   - Temperature reached – 900-1300 °C
   - Exposition time ~10 ms
   - No clear indication of oxidation, generated damage induced by thermo-mechanical stresses (not representative of stresses from proton beams)

2. Graphite exposed to 1200 °C in oven for both Sigrafine (SGL)
   - Sigraflex tests ongoing as we speak

3. Tests also at 2500 °C for short-term on Sigrafine (10 s) (SGL)
Results of oxidation tests (Sigrafine)

- Reaction observed after the air meets the graphite surface
- After 1000 s, holes observed on the surface
- Mass loss remains limited: ∼1% for 100 s, ∼4% for 1000 s
  - In the real application, T is >400 °C for 1 s after each dump → 100 s roughly equivalent to 100 dumps
  - Expected slightly higher factor for Sigraflex
- Tests at 2500 °C excluded the possibility of massive oxidation
Comments on graphite oxidation

- As well known, graphite is sensitive to oxidation at high temperature
- Oxidation highly dependent on temperature and exposition time
- At significantly high T (>1500 °C) oxidation limited to surface, for exposition times of 10 s for Sigrafine
- Greater mass loss observed for longer exposition times, but still attack limited to surface
- All tests more pessimistic that actual conditions in TDE
  - Report at the 153rd MPP meeting
  - Comprehensive report including all these studies being written. Expected to be released by beginning 2018
- Running the dump in air would be a degraded mode scenario, but acceptable if operation limited in time
Outlook for YETS and 2018 operation
Identified weak points potentially affecting 2018 operation

1. N₂ bottles exchange
   - Could entail several hours of downtime if not in the shadow of another intervention
   → installation of a N₂ line

2. Risk of breaking DS window (+ gaskets)
   - Could lead to even bigger leaks
   → Modify the window on a spare core (DdD on operational dump ~20 mSv/h)
Installation of $N_2$ line to dumps – YETS17-18

- LHC-TDE-EC-0003 installation of a stainless steel pipe nitrogen line from P6 surface to UD62 and UD68 – approved during LMC331
- Both dumps to be done
Advantages

- In case of issues with bottles or with an increased leak, possibility to decouple $N_2$ bottle replacement and LHC operation
- Not anymore slightly radioactive bottles to manage as activated waste

Risks

- Leak along the $N_2$ line $\rightarrow$ leave possibility to connect bottles at current location close to dump with a separation valve
- Need of large $N_2$ overpressure not necessary if $N_2$ atmosphere/flux maintained to avoid any core oxidation – UD68 stable condition should not be changed
New design of DS window

- No need for destructive work in the tunnel
- Welding of a new 318L flange on the existing 318L one
- Ti64 window screwed on the 318L assembly with ConFlat flanges
New TiGr5 window design
Proposed solution investigated for YETS17-18

- Modification UD68 spare core directly in the UD cavern – operational dump not touched!
Procedure being investigated:

- Turn the dump by 180° in order to expose the downstream window at the end of the TD tunnel (lower DdD)
- Installation of the dump in the turning gear
- Remove the current TiGr2 window
- Weld and assembly of the new TiGr5 window
- N₂ leak tests
- Put back the dump in the original (spare) location

Current dose rate max 100 μSv/h at contact (dominated by dose rate of operational core)

Timeline: assembly in the UD towards mid-February + 2 weeks to complete
Instrumentation

- In the assumption that a modified spare core is installed in the machine, **active instrumentation** can be foreseen (currently operationally blind):
  - **Interferometers** (US#1/2) (already installed but out of service – to be repaired in YETS17-18)
  - **Fibre-optics based strain gauges** on the core (YETS17-18)
In-situ procedure

- **Advantages:**
  - No removal from the tunnel of cores
  - Avoid large transport on QRL (still welding material will have to pass)
  - No opening of shielding interfering with YETS activities
Status

- Procurement of 318L + TiGr5 flange ongoing
  - Machining and preparation of 318L and TiGr5 on the critical path, still to be validated pending the timely procurement of raw material
- Definition of welding procedure
- Definition of the WDP with RP (ongoing)
- Coordination with ACE on planning
Reasons to modify spares

- Evolution of the leak cannot be predicted
  - Leak detection on UD62 with \( N_2 \) and He proposed for YETS
  - Might be forced to run a dump in air
- UD68 dump leaking on back window, UD62 probably also (TS2 intervention non conclusive in this respect)
  - Source of leak not clear, could be gaskets damaged by fatigue
  - Not clear if fatigue is due to large number of total dumps or vibrations from more recent operational beams
  - Dismantling required to verify leak source (LS2)
- Not clear if the not-modified spares could start leaking due to 2018 beam operation
Proposed course of actions

- Install N\textsubscript{2} lines for both dumps
- Leave untouched the UD68
- UD62
  - Prepare the modified spare (with mentioned caveats)
  - N\textsubscript{2} leak detection
  - Depending of the finding (large leak prone to evolve further) decide on the installation of the modified spare. No evidence today for a need to change the dump
  - High probability that no intervention will be needed
- No limitation for operation in 2018 if leak does not evolve or (modified) spare installed.
Conclusion

- 2017 LHC dump block operational year limited by:
  - Conservative assumption in graphite behavior when exposed to air
  - Significant leak in the UD62 dump DS window forced unforeseen replacement of N\textsubscript{2} bottles

- Perspectives for 2018:
  - Install N\textsubscript{2} lines for both dumps
  - Leave untouched the UD68
  - UD62 $\rightarrow$ Prepare the modified spare

- No limitation for operation in 2018 expected if leak does not evolve or (modified) spare installed
Current configuration – Ti2 window with helicoflex gaskets

New proposed configuration – Ti5 window with CF gaskets