SUMMARY OF THE SESSION III: REPAIR OF 34

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INTRODUCTION

After the incident in sector 34, magnets along a zone of about 700 m had to be removed from the tunnel and need to be repaired or exchanged. Although this is a major incident, it should not be forgotten that this represents only a few % (about 3%) of entire LHC.

Some pollution due to soot is extending beyond the zone where magnets are removed. Pieces of superinsulation were found along the entire arc. The damage to other equipment in the sector is very limited.

In the session four presentations were given to discuss the repair in sector 34, and one presentation to discuss the consequences of such incident or other consolidation work after beam operation:

- Magnets repair for sector 34, L.Rossi and M.Modena
- Reinstallation and interconnections, Francesco Bertinelli
- Vacuum system – how to get ready for beam? V.Baglin
- Other systems – what needs to be done? Repair and reinstallation of other systems (standard QPS, PC, BLM, Cryo, Survey, …), M.Solfaroli Camillocci
- Consolidation after beam operation – constraints from radiation protection considerations, D.Forkel-Wirth

MAGNETS REPAIR FOR 3-4 SECTORS

The incident in sector 34 has affected some 50 main LHC magnets. Such a scenario was never considered as realistic in the past. The reserve of magnet has been barely sufficient (some 40 cryodipoles and 14 Short Straight Sections (an SSS includes quadrupole + corrector magnets), in some cases the reserve magnet types are not compatible with the one damaged.

Furthermore the subsequent measurements on two other sectors have shown the necessity to replace two other dipole magnets.

Many SSS variants exist. After the reinstallation in sector 34 some correctors will be lost due to reshuffling, but no major impact on beam operation is expected.

For the repair, a quick restart of the facilities, requiring an impressive logistics effort was achieved.

Magnets reused or remaining in the tunnel are inspected (visual, electrical, cold test for the removed magnets,…) but defects could be missed so cautious repowering procedures are required. The last magnet should be lowered in calendar week 15.

Operations to rebuild a stock of spare magnets will start as soon as possible with the recovery/repair of the damaged magnets.

REINSTALLATION AND INTERCONNECTIONS

Reinstallation of the first magnets in the damaged zone has started in parallel with the removal of damaged magnets. It is planned to reinstall the last magnet by end March. QRL service modules, especially the interface for connection to cryomagnets (jumpers) needs to be repaired in four locations.

Making interconnects is a complex chain of operations, the last interconnect will be closed in week 23. The interconnection (IC) work requires a minimum chain of adjacent magnets and their alignment. Quality Control issues are particularly important, both in order to reproduce past quality in the new conditions, and of course to improve on critical aspects.

IC work will also continue in parallel outside the damaged zone in 34 and in all other sectors during the shutdown. There are several other interventions in stand alone cryostats.

The sectors that are being warmed up (such as sector 12 and 67 to exchange a dipole magnet and sector 56 for the repair of connection cryostat) require an RF ball test to locate PIMs to be replaced and finally validate the free beam tube aperture.

The replacement of the undulator in L4 needs to be decided, it is likely that it is delayed.

The planning is very optimistic and the schedule is tight, for both, preparing the magnets and for reinstallation. Quality must not be compromised.

The new interconnects will present less risk as the quality control is enhanced. Clamping main busbar interconnects would be excellent, but adding a non fully validated clamping system could create other problems.

VACUUM SYSTEM – HOW TO GET READY FOR BEAM?

During the incident of sector 34, the two beam vacuum sectors of 2.8 km each and four insulation vacuum sectors i.e. 750 m were vented to atmospheric pressure. Besides the mechanical damages of the nested bellows and plug-in-modules due to the movement of the cold masses under the helium pressure, soot and debris of superinsulation were spread inside the beam and insulation vacua from Q6R3 till Q6L4. About 59% of the beam vacuum was contaminated with Multi Layer Insulation (MLI) and 19% with soot (the beam vacuum in one sector has a length of ~6 km).

Ultra High Vacuum system does not mean that the systems must be Ultra Clean. Therefore it was decided to perform cleaning of the beam tubes in situ, the progress is impressive.

From the magnets that have not been brought back to surface, the soot pollution concerns six cryo dipoles. After the cleaning, some soot will remain between beam screen and cold bore. Could this be an issue for beam operation? In some locations, an oxide layer coming probably from the melting of an ice block appeared during warm-up is present. The thickness should be in the nano meter range so acceptable for the impedance of the machine.

No problem was found in the warm sectors, in particular in the zone with RF cavities that require ultraclean conditions.

Ideas that were discussed after the presentation:

- Could an extra test on a cold test bench be done to quantify the effect of soot in presence of magnetic field?
- Extra instrumentation is discussed as diagnostic tool during operation, such as Beam Loss Monitors to be installed along the magnets in part of sector 34. This would help to identify locations where some debris gets into the beam.
- Theoretical simulations could be done to evaluate the effects of MLI, soot and oxide layer on the beam.

OTHER SYSTEMS – WHAT NEEDS TO BE DONE? REPAIR AND REINSTALLATION OF OTHER SYSTEMS (STANDARD QPS, PC, BLM, CRYO, SURVEY, …)

Compared to the damage to the magnets there was very limited damage to the infrastructure after the incident (tunnel concrete, cables, etc.) and to other equipment (electronics, instrumentation,…).

However, a large amount of equipment from different systems (such as QPS racks, PC, BLM, Cryo instrumentation control etc.) located in the tunnel of sector 34, especially in the damage zone, was removed in order to allow an easy damage inspection. After a change or repair, during the re-installation phase, the equipment must be put back in the tunnel and re-tested.

Many QPS heater power supply seem to have suffered from an electrical breakdown that needs to be understood. A few power converter failures are being investigated.

Before re-commissioning the magnet circuits, short-circuit tests of the power converter need to be done to demonstrate that the converters are fully operational, time needs to be allocated and a 24h heat run must be performed.

In parallel to the repair, many other activities are taking place in the sector (see also session V).

Already before the incident, a non conformity was found on the DSLC (a cryogenic link that is several 100 m long). After the repair, the circuits powered by the link in point 3 will have to be fully re-commissioned.

There is some cabling activity for two magnets, RQT4 and RQT5.

If time is available, BSRT, the synchrotron light telescope will be realigned and an optical bench will be changed.

CONSOLIDATION AFTER BEAM OPERATION – CONSTRAINTS FROM RADIATION PROTECTION CONSIDERATIONS

Since 10th September 2008 a major part of the LHC installation is classified as Supervised Radiation Area.

Only radiation workers are allowed to access this area (DIS dosimeter required). Any destructive work (machining, grinding, etc.) on radioactive components has to be announced to SC-RP, work procedures to be discussed with and approved by SC-RP prior to the start of the work. The risk of contamination for any non-destructive work can be excluded. The dose to personnel during maintenance during this shutdown is expected to be negligible.

All material that had been in the LHC tunnel during beam operation and that will leave the LHC needs to be controlled by SC-RP.

A considerable amount of LHC accelerator equipment can be declared as non-radioactive (after control by RP). Consequently, simplified repair procedures and repair techniques inside the tunnel can be authorized by RP.

Equipment (declared as non-radioactive by RP) can be repaired in ordinary work shops or sent to any company for repair or modifications.

As soon as LHC operation will be resumed in 2009, beam losses will inevitably increase the activation of accelerator and detector components. Maintenance and repair teams risk to be exposed to elevated radiation levels.

RP constraints for repair, maintenance and installation will become severe after restart of the machine. Special procedures including use of special tooling need to be respected. Radioactive equipment can be only sent to few, specialised companies.

The arc magnets are expected to become slightly radioactive, with an ambient dose equivalent rates in the order of few uSv/h inside and some few 100 nSv/h outside the cryostat. Other parts of the machine will become more activated.

The radiological risk involved in repair and maintenance is tolerable – but procedures and tooling (e.g. no grinder!) need to be qualified for work on radioactive items.

To reduce dose to personnel, consolidation and repair work should preferably be done during the present shut-down.

The information obtained by radiation monitoring on beam losses, in combination with Monte Carlo calculations and screening measurements would allow a simplified RP approach to the radiological classification of material. One specific read-out tool for various radiation monitoring systems would be useful.

A centralized workshop for work on activated material is favoured to avoid separate workshops for different groups where mix between conventional and activated material could occur. This has to be assessed at the accelerator sector level.