SUMMARY OF BEAM VACUUM ACTIVITIES HELD DURING THE LHC 2008-2009 SHUTDOWN

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Abstract

At the start of the CERN Large Hadron Collider (LHC) 2008-2009 shutdown, all the LHC experimental vacuum chambers were vented to neon atmosphere. They were later pumped down shortly before beam circulation. Meanwhile, 2.3 km of vacuum beam pipes with NEG coatings were vented to air to allow the installation or repair of several components such as roman pot, magnets kicker, collimators, rupture disks and masks and re-activated thereafter. Beside these standard operations, "fast exchanges" of vacuum components and endoscopies inside cryogenic beam vacuum chambers were performed. This paper presents a summary of all the beam vacuum activities held during this period and the achieved vacuum performances.

SHUTDOWN ACTIVITIES

After the sector 3-4 incident the 19th September 2008, the start of the shut-down 2008-2009 was advanced by 3 months to November 2008. Its duration was driven by the repair activities of the sector 3-4; the evacuation to the surface and the preparation of the magnets, their transport and their re-installation underground. In addition to the sector 3-4 activities, maintenances, consolidations and repairs were originally planned. This was also the case for the repair of the vacuum leaks in the injection dump (TDI) and in the schottky monitor, the repair of the stainless steel motor rails of some collimators and the replacement of one injection kicker (MKI). The completion of the LHC machine with the installation of all phase 1 collimators, dilution kickers (MKB), roman pot in ATLAS, beam position monitors (BPM) and safety rupture disks were also scheduled. Finally, new activities came up during this shutdown such as the exchange of a Penning gauge in the LHCb vacuum sector and the endoscopic inspection of the plug-in-modules (PIM) inside the beam vacuum system held at cryogenic temperature. LHC was back in operation by December 2009.

LONG STRAIGHT SECTIONS

The main activities involved in all the room temperature long straight section (LSS) are listed and described below:

- Final installation and repair of phase 1 collimators:

Figure 1 shows a summary of the total amount of collimators installed in all the LSS sectors. The number of new collimators installed during the shutdown equals to 16 and the number of repairs carried out due to the failure of the stainless steel motor rail equals to 20. In all cases, installation and repair of a collimator require a venting of the vacuum sector with bake-out mounting / dismounting and vacuum activation of the NEG chambers. A total of 27 vacuum sectors were vented in order to perform these tasks. The cumulated length of the NEG chambers reactivated during this activity is equal to about 1.5 km.

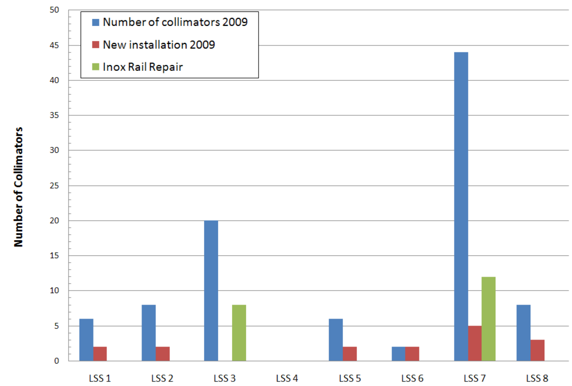

Figure 1: Number of collimator phase 1 installed and repaired in all the LSS.

- Installation of MKB in the dump lines:

The LHC beam dump system shall include 4 horizontal blow-up kicker magnets (MKBH) and 6 vertical blow-up kicker magnets (MKBV) per beam. For cost reasons, the production and installation of the MKB's have been staggered. At the LHC start-up in 2008, 2 MKBH and 2 MKBV magnets per beam were installed. During the shutdown 2008-2009, 3 additional MKB's per beam were put in place. An upgrade of the vacuum instrumentation with an installation of a turbo molecular pump and vacuum gauges for each MKB was also done.

- Installation of a roman pot ALFA for ATLAS:

The ATLAS ALFA project is based on detectors that aim at absolute luminosity measurement in the interaction point 1 (IP1). For the shutdown a first detector was delivered. It was installed about 250m from the IP1 in the A7L1.B room temperature vacuum sector. This sector was vented to atmospheric pressure and then, once the roman pot was installed, the bake-out and activation of NEG was performed. The achieved pressure is ~ 5 10^{-12} mbar.

- Repairs of both Target Dump Injection (TDI)

The TDIs for LHC are mobile beam obstacles that are used during the adjustment of the injection trajectory and protect the experiments and superconducting machine elements in the event of a malfunction of the injection kicker. During injection, the beam passes through 5 horizontally deflecting steel septum magnets, and four module of vertically deflecting kicker (MKI). The TDI is placed about 70 m downstream from the MKI, and about 15 m upstream from the cold separator magnet D1. During the first LHC commissioning and bake-out of the

TDI in the LSS2, a leak located on a thermo coaxial connexion appeared. After having fixed the problem and a second bake-out, a high pressure (5 10^{-10} mbar) was still measured without apparent sign of external leak. At the beginning of the shutdown, in order to investigate the problem better, it was decided to isolate the TDI and perform a bake-out of it in the tunnel. During this study, a new external leak on another thermo coaxial cable appeared. So, it was finally decided to remove all the thermo coaxial cables installed on the jaws of the TDI. The two tanks were removed from the tunnel, transported to the surface and completely dismantled. It turns out that on both tanks the thermo coaxial cables were damaged, resulting in a high internal degassing. In less than 3 months, both TDI were modified, successfully tested and then installed again in the LHC machine. The TDI pressure is now 10^{-10} mbar.

- <u>Repair of a schottky monitor in LSS4</u>

After the bake-out and vacuum activation of the vacuum sector A7R4.R, an unusual argon presence inside the sector was detected by a residual gas analyzer. After different analysis and tests, it was found that the origin was a coaxial cable backfilled with argon located inside a schottky monitors installed in the vacuum sector. During the shutdown the tank was dismantled, transported to the surface for repair and then reinstalled on the vacuum sector. Finally, bake-out and activation of the sector were done to resume the performance (pressure 2 10^{-12} mbar).

- <u>Installation of 4 button electrode pick-ups in LSS 1 and LSS 5:</u>

The installation of these 4 new button electrode pick-up were required to allow the BPM system to satisfy the forward physics detector of both ATLAS and CMS during high β* running with low bunch numbers and zero crossing angle. This activity implied the venting of 4 room temperature vacuum sectors in front of the inner triplets (the focusing quadrupoles located beside each experiment), the mechanical installation of the BPM and the bake-out of the vacuum system.

- <u>Installation of safety rupture disks</u>

In the event of an incident inside an inner triplet, a liquid helium release could provoke an excess pressure inside the beam pipes of the experiments which could seriously damage these vacuum chambers. For this reason, 8 safety rupture disks were installed on the vacuum sector just after the inner triplets about 20m from the IP. Since these sectors could be isolated from the experimental vacuum chambers by a sector valve, allowing the installation of the rupture disk and the consequent bake-out, the work could be done without venting the experimental vacuum system. However, during beam operation, these sector valves are locked open allowing in case of incident the release of any excess pressure through the rupture disks.

Others minor activities related to the room temperature vacuum sectors consisted mainly of realignment of BPMs, exchange of an MKI and exchange of interconnecting modules due to RF fingers protruding inside the vacuum chambers.

All the activities related to the room temperature vacuum sectors of the LHC during the shutdown period of 2008-2009 involved 60 vacuum sectors and 2.3 km to be vented, re-pumped and baked-out again. Figure 2a and 2b show the percentage of vacuum sectors and length concerned by each of these activities.

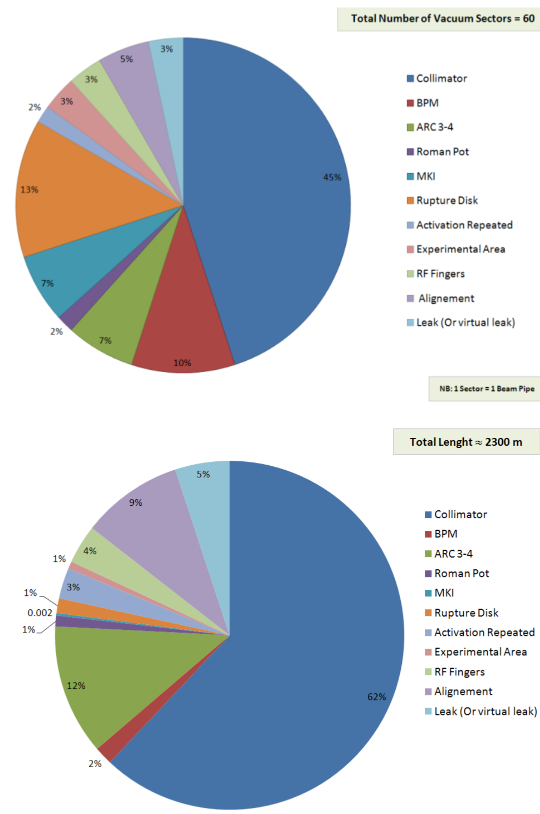

Figure 2a and 2b: Percentage of number and length of vacuum sectors concerned by the shutdown activities.

ARCS AND STAND ALONE MAGNETS

Beside the cleaning recovery of the beam vacuum and the closure of the sector 3-4 [1], activities were also held in the cryogenic areas. A superconducting dipole was removed from the arc 1-2 and 6-7 and superconducting links were repaired in arc 4-5 and 6-5. These activities required leak testing and vacuum evacuation. In parallel, whilst the cryogenic sectors were emptied or left floating, all the vacuum sectors were evacuated during at least a month before the final cool down in order to minimise the condensation of gas.

ENDOSCOPY IN THE CRYOGENIC BEAM VACUUM

To access and repair a leak of a flexible hose located in the insulation vacuum of 2 distribution feed boxes (DFBA); 200 m of the arcs 8-1 and 2-3 were warmed up to room temperature while the remaining part was left at a floating temperature of 40K. For safety reasons, the arc could not be left actively cooled by the cryogenic loops. So, during the 2 weeks intervention, the temperature of the floating part of the arc increases by ~ 2.5K per day. The mechanical behaviour of the PIMs located at the transition region between the room temperature part and the cryogenic temperature part was checked since above 80K a PIM could buckle due to thermal dilation [2]. Thus, endoscopic inspections inside the beam vacuum chamber were performed to validate the repair. In order to prevent any possible retro diffusion of air and thus condensation of water inside the cold vacuum chamber of the arc, ultra pure neon was injected during the inspection. An overpressure of 10 mbar was fixed in the vacuum chamber before the opening and during the endoscopy a constant flow of 250 l/h was maintained. Figure 5 shows the picture of a conformed PIM taken during the endoscopy which validated the repair.

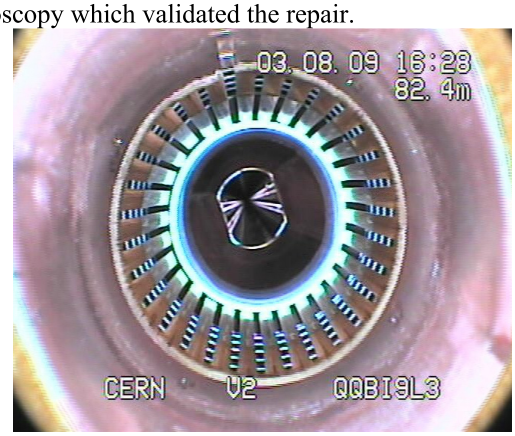

Figure 5: Endoscopy of a conformed "plug-in" module.

EXPERIMENTAL AREA

Following the bake-out and the vacuum activation of the NEG in June 2007, all the vacuum chambers of the four LHC experiments (ATLAS, ALICE, CMS and LHCb) were vented to atmospheric pressure with ultra-pure gas for the shutdown period.

In order to optimise the vacuum chamber wall transparency to particles, the thickness of the experimental vacuum chamber was minimised such that the maximum differential pressure that the chamber wall can withstand is about $1.5\cdot10^5$ Pa. So, when such chambers are left under vacuum, a light knock occurring during the shutdown could lead to buckling. Consequently, filling at atmospheric pressure with noble gases is required. Ultra-pure neon is used to this mean to preserve the NEG characteristics at their best since it is not pumped by the getter.

The gas injection system consists of a gas purifier and an injection line. The gas purifier is a UHV system designed to inject purified neon gas up to atmospheric pressure into the experimental beam chambers and to pump the pure neon without contamination. At the beginning of the shutdown period all the experiments were vented to atmospheric pressure of pure neon. Then, 1 month before the restart of the machine, the ultra pure neon was re-pumped from all the experiments and no significant change in the pump down and final pressure of the experiments related to the neon injection and pump down was observed.

FAST EXCHANGE COMPONENT WITH PURE NEON INJECTION

Following the ultra-pure injection of neon at atmospheric pressure on the LHCb experiment, a connection of a penning gauge was found bent. The chance of having a leak through the connection was high thus it was decided to exchange the gauge without venting to air the NEG activated experimental vacuum chambers.

A dedicated neon venting system was developed at CERN that enables short mechanical intervention in all the LSS sectors without losing too much of the pumping speed of the already activated NEG [3]. The principle is to continuously over-pressurize the vacuum sector with a gas which is not pumped by the NEG, exchange the faulty component and then pump down the sector again. The neon over-pressurization in the vacuum sector preserves the NEG from saturation during the exchange of the faulty component, thus avoiding air back streaming through the beam pipe aperture. Nevertheless, the exchange of this gauge was challenging due to a special boundary condition: the VELO detector of LHCb has a fragile aluminium foil between the detector volume and the beam vacuum. This foil is designed to withstand a differential pressure between the beam pipe and the detector of –5 ÷ +2 mbar. We succeeded in exchanging the gauge and after pump down of the ultra pure neon in the LHCb experiment, the ultimate pressure reached on the gauge was the same as measured previously, meaning that no visible contamination and therefore no saturation of the activated NEG occurred during the exchange.

FUTURE PLANS

The next shut down period is foreseen for 2011–2012. For the time being maintenance activities, a number of consolidation and repair/upgrade items have already been identified. Activities connected with the installation of collimators phase 2 are already planned and they will concern mainly the LSS 3 and LSS7.

ACKNOWLEDGEMENTS

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