VACUUM PERFORMANCES OF SOME LHC COLLIMATORS

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Abstract

With the first beams circulating in the CERN Large Hadron Collider (LHC), pressure increases are observed at some collimators positions. This paper describes the collimators vacuum performances measured in the laboratory and also performances obtained in the machine. Based on these observations, estimations of some operational behavior such as pressure increase and NEG reactivation scenario are given.

INTRODUCTION

The restart of the LHC with beams has been taken place from the end of the year 2009. The beam vacuum system of the Long Straight Section (LSS), which is designed to operate at room temperature, relies on the pumping speed of the Non-Evaporable Getter (NEG) coatings and ion pumps [1]. This technology was born and industrialized at CERN. The pumping capacity of the NEG has been measured for single gas as a function of the quantity of molecules absorbed [2]. In the LHC ring, heterogeneous gas loads are expected from the collimators especially by moving its jaws or resulting from the impact of the primary beam particles and secondary particles on to the collimators jaws or absorber blocks. The gas load from these devices, made out of light materials like Carbon-Carbon structures or Boron-Nitride , will be pumped by the NEG coated beam pipes and ion pumps, which are installed upstream and downstream.

In order to predict the time between two NEG re-activations and the evolution of its saturation due to these gas loads, laboratory measurements with a spare LHC collimator were performed. In this report, first some results from the movement of the LHC collimator jaws and the beam injected directly on the jaws will be presented. Next, the laboratory setup for collimator's outgassing measurements will be described. An estimation of the NEG lifetime due to those outgassing will be given. Finally, we will briefly show our next experimental plan by using NEG chambers and a spare collimator.

DYNAMIC PRESSURE IN LHC COLLIMATOR SECTIONS

During the LHC operation, there are two factors which induce pressure increase in the beam pipe related to the collimators: the movement of the collimators' jaws and the impact of the beam on the jaws. Fig. 1a shows the pressure increase observed when the jaws of a collimator are moved. Fig. 1b shows the relation between the pressure increase and the length of the jaw movement for

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two Bayard-Alpert vacuum gauges positioned at the different distance from another collimator. It is noticed that there is almost a linear relation between the pressure increase and the distance the jaw moved.
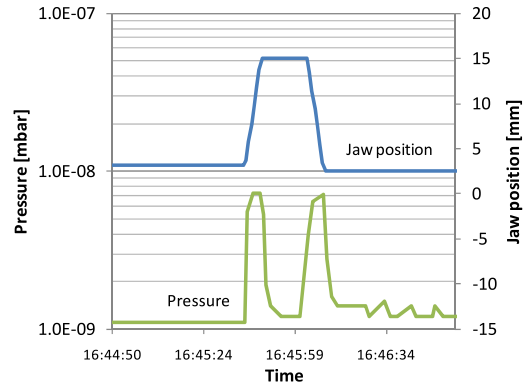

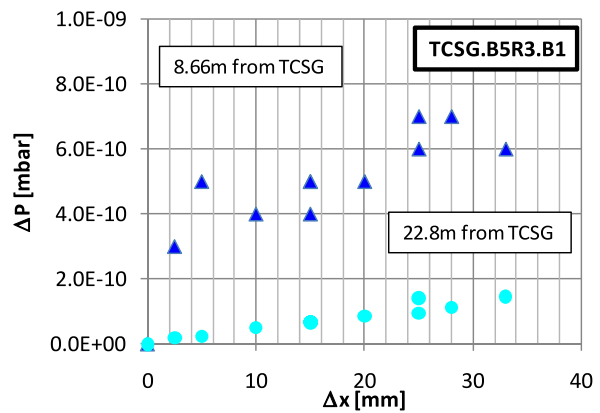Figure 1a: Pressure increase while moving a collimator jaw.

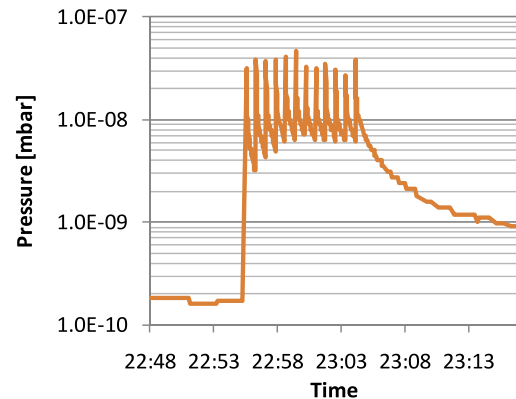Figure 1b: Pressure increase as a function of the jaw's movement length.

Figure 2: Pressure measured by the nearest gauge of the target dump injection (TDI) while shooting the beam directly onto it.

Fig. 2 shows the pressure increase when the 450 GeV beam with intensity of $5 \cdot 10^9$ protons is directly intercepted by the collimator's jaw. It is worth mentioning that Pb ions with a similar intensity give the same result. Although it's difficult to quantitatively discuss the results at this stage, the beam effect will be evaluated by future measurements in the laboratory by measuring the outgassing as the function of the jaw temperature.
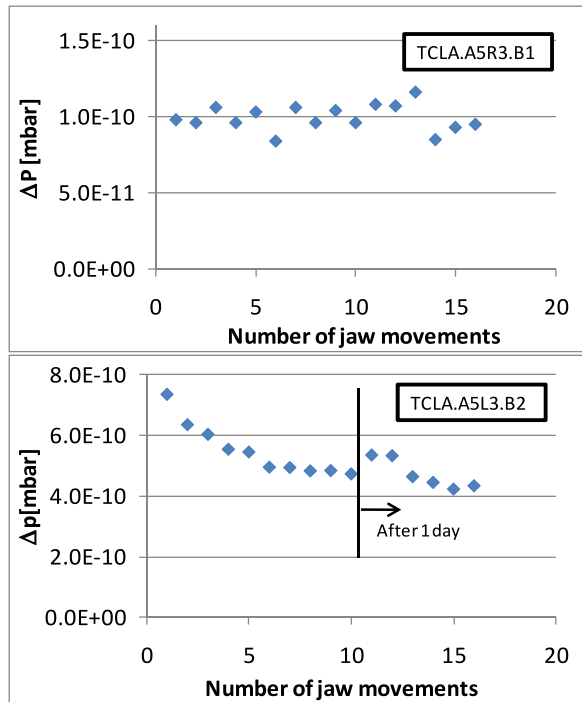

Figure 3: Pressure increase by the repetition movements of jaws.

Figure 3 shows the pressure increase where moving the jaw repeatedly. As seen in the upper figure, no significant change was observed for the collimator TCLA.A5R3.B1. However, for the collimator TCLA.A5L3.B2, the pressure increase was decreased by about factor 2 due to the repeated jaw movements. However, this benefit was lost in some degree after one day without the jaw movement.

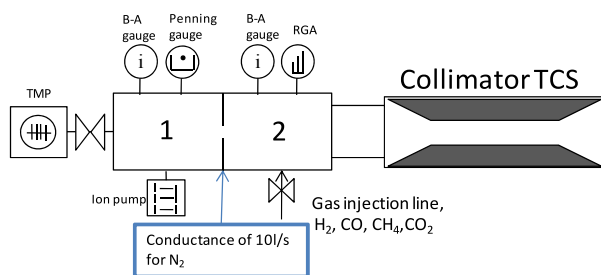## MEASUREMENT OF COLLIMATOR OUTGASSING RATE

Figure 4: Experimental setup for the measurement of outgas from a collimator.

Experimental Setup

The experimental setup to measure the collimator outgassing rate is illustrated in Fig. 4. In this measurement, a secondary collimator (TCS), whose jaws have C-C structure, was used. An orifice with a known conductance of 10 l/s for N_2 was used to separate the two domes. A pressure without collimator installed of about $3 \cdot 10^{-10}$ mbar was measured in the system and a background outgassing rate of $3 \cdot 10^{-10}$ mbar l/s was estimated. The residual gas analyzer (RGA) was calibrated after each bake-out by using the gas injection line shown in Fig. 4.

Table 1: Outgassing rate without the jaw movement and gas load with the jaw movement of 30 mm. The values are nitrogen equivalent

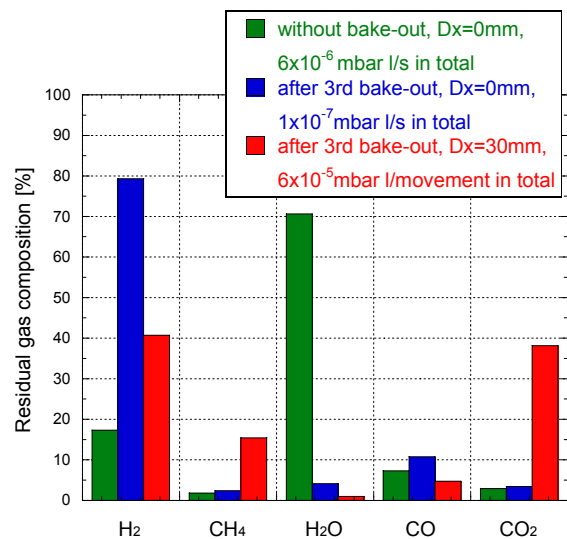| Status	Outgassing rate [mbar l/s]	Gas load [mbar l /movement] $\Delta x_{jaw} = 30$ mm
Before bake-out	$7 \cdot 10^{-6}$	$1 \cdot 10^{-4}$
After 1st bake-out	$7 \cdot 10^{-8}$	$8 \cdot 10^{-5}$
After 2nd bake-out	$5 \cdot 10^{-8}$	$6 \cdot 10^{-5}$
After 3rd bake-out	$4 \cdot 10^{-8}$	$5 \cdot 10^{-5}$

Figure 5: Percentage of the residual gas composition before, after bake-out and with the jaw movement. The values of the sum of the residual gas composition are also shown.

Outgassing Rate

The total outgassing rate (N_2 equivalent) for the TCS studied, with and without the movements of the jaws is shown in Table 1. The integrated outgassing rate for the jaws movement of 30 mm is also shown. We performed 3 bake-out, in order to study the vacuum performance of the TCS collimator as a function of the number of bake-out.

A decrease of the total outgassing rate of a factor 1.3 was measured after each time. In the static case, which is without moving the jaw, the total outgassing rate could be decreased by about two orders of magnitude by the bake-out. However, in the dynamic case, the decrease corresponds to a factor 2 even after the 3rd bake-out.

The percentage of the outgassing gasses species is shown in Fig. 5. Partial pressures were estimated by a calibrated RGA and Bayard-Alpert gauges. The main gas component for the unbaked system is H_2O as normal. H_2O is decreased by the bake-out and the main component after bake-out is H_2. The ratio of each component with the jaw movement of 30 mm after the 3rd bake-out is also shown in Fig. 5. It is noticed that the main component for the static case is H_2, while the carbon related components like CH_4 and CO_2 accounting for larger share of the total outgassing amounts when the jaw is moved.

Fig. 6 shows the gas components dependence as a function of the jaw movement's length. The upper panel show the non-baked case and the lower shows the baked system. As in the case of the LSS in the LHC, which was shown in the Fig. 1, a linear relation between the amount of released gas and the distance of the jaw movement was found. For the unbaked system H_2O is the main component also in the case of the jaw movement. After the bake-out in the static case H_2 is the main component, however as the collimator's jaws are moved, a higher effect of carbon-related components take part to the total outgassing.
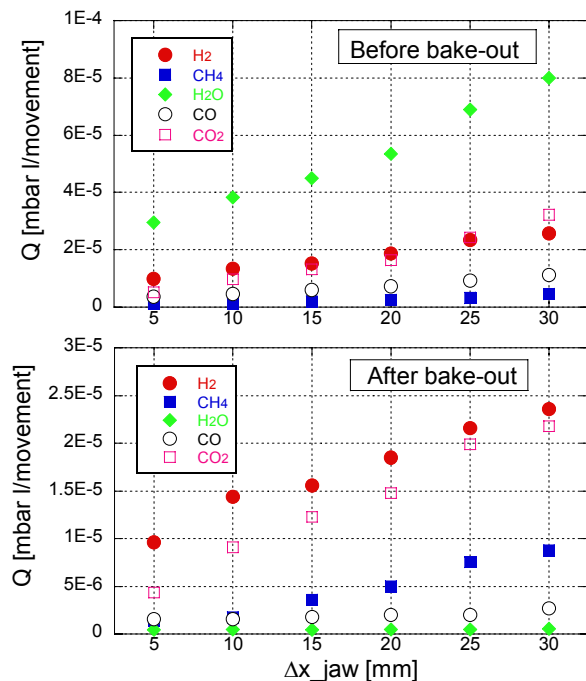

Figure 6: Outgassing amount of each component when the jaw was moved by each distance before and after bake-out.

Estimation for NEG

Pumping capacity of NEG coatings for different gases was measured in laboratory [1, 2]. Here we could try to estimate the effect of a collimator on the NEG lifetime and foreseen how the pumping speeds and pumping capacity will vary as a function of time.

The NEG coating capacity for CO was estimated to be $5 \cdot 10^{14}$ molecules/cm^2. This value corresponds to a reduction of the pumping capacity by about a factor 2. The TCS outgassing rate for CO, in the case of a baked system, is estimated to be about $2 \cdot 10^{-8}$ mbar l/s, which corresponds to $4 \cdot 10^{11}$ molecules/s. For a hypothetic 1 m NEG coated vacuum pipe with an internal diameter of 80 mm, the NEG lifetime is estimated to be 30 days. For CO_2, the capacity of NEG is the same as CO. Because of the outgassing rate of $5 \cdot 10^{-9}$ molecules/cm^2 for CO_2, the NEG life for the 1 m vacuum pipe is estimated to be 90 days. In the LHC accelerator, ion pumps of about 30 l/s for N_2 are installed upstream and downstream to the collimators in order to significantly decrease the gas load to the NEG. During the jaws movement up to 30 mm, the total outgassing of $3 \cdot 10^{-6}$ and $2 \cdot 10^{-5}$ mbar l/movement for CO and CO_2 respectively was released. From this amount, it can be concluded that the 1m NEG chamber will be saturated by about 1100 cycle of movement of the jaws, which is happily very large time.

SUMMARY AND THE NEXT PLAN

The outgassing rate of a collimator, TCS, was measured before and after bake-out. For both cases, the component of the outgassing was measured without and with the jaw movements. As expected, H_2O is the main component before the bake-out. Although H_2 is the main component after bake-out, a large amount of carbon related components were observed in the case with jaw movement. To specify the source of outgassing, measurements of the outgassing rate of a sample of carbon, which is used as the jaw material, will be done near the future. Outgassing rate from this sample will be measured through accumulation method. By this method, the small amount of outgassing rate can be measured by making the accumulation time long enough to reach enough gauge sensitivity. In order to estimate the beam effect, we plan to measure the temperature dependence of the outgassing rate from the collimator assuming that the beam effect can be simulated by the high temperature. Furthermore, as described above, we are now constructing the next setup where a collimator is combined with NEG chamber. The transmission rate through the NEG will be directly measured by that system.

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[2] C. Benvenuti, P. Chiggiato, P. Costa Pinto, A. Prodromides, V. Ruzinov, Vacuum 71 (2003) 307-315.