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THE LEP VACUUM SYSTEM: A SUMMARY OF 10 YEARS OF SUCCESSFUL OPERATION

J.C. Billy, J.P. Bojon, O. Gröbner, N. Hilleret, M. Jimenez, I. Laugier, P. Strubin

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Abstract

The LEP accelerator is now operating regularly above 100 GeV and its vacuum system is submitted to the impact of energetic photons with a critical energy approaching 1 MeV. The consequences of this high energy on the photon induced desorption will be reviewed in the light of the various photon absorption mechanisms for aluminum. A review will also be given of the ten years of operation of the LEP vacuum system concerning more especially the evolution of the dynamic pressure with the beam dose and energy, the main difficulties experienced and the actions taken to overcome them.

1 INTRODUCTION

The Large Electron Positron storage ring (LEP) exceeded in 1999 the LEP200 design energy and produced collisions between two beams of electrons and positrons circulating at energies E_b greater than 100 GeV per beam. This contribution will present the behavior of the vacuum system in the presence of these high energy beams radiating on the vacuum chamber a synchrotron power exceeding 1 kW/m. One of the main peculiarities of LEP from the vacuum point of view is the very high critical energy of the photons radiated by the beams (more than 700 keV). The consequence of this unusual situation on the amount and on the composition of the desorbed gas during operation will be described as well as its consequences on the beam-gas lifetime. Finally, after more than ten years of operation, the time is also come to review the incidents having hampered the operation of this accelerator. On the vacuum side, these incidents are mainly leaks and this contribution will show their nature, the components affected and their effect in terms of "downtime" for the accelerator.

2 OPERATION OF THE LEP VACUUM SYSTEM ABOVE 100 GEV

To illustrate the behavior of the LEP vacuum system above 100 GeV, the pressures measured around the interaction point (I.P.) 2 are displayed in figure 1 as a function of the distance to the I.P. in the presence of a 4 mA beam at 103 GeV. The pressure in the arc, directly exposed to the synchrotron light is in the mid 10^{-7}Pa range. Closer to the I.P., the operation of normal conducting accelerating cavities produces an extra gas load which raises the pressure in the same range. In the region of the superconducting cavities, the strong cryopumping decreases the pressure below 10^{-7} Pa despite the very high (7 MV/m at 352 MHz) accelerating field. Closer to the I.P., the pressure decreases to reach the 10^{-10} Pa range.

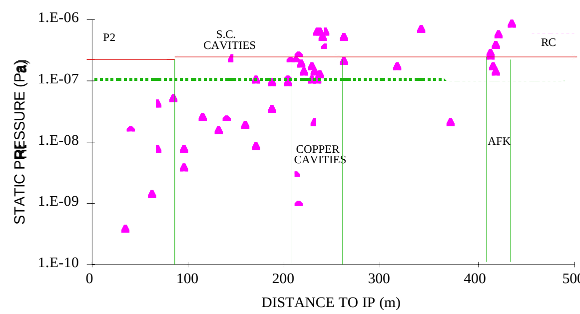


Figure 1: Pressure distribution around I.P.2 at 103 GeV, 4 mA

2.1 Lifetime

The evolution of the product beam intensity x beam-gas lifetime [1] ($I*\tau$) measured at 101 GeV during the first part of year 2000 is shown in Figure 2 for the electron and positron beams. The actual ($I*\tau$) is close to 800 mA*h.. In large accelerators where a regular and reliable pressure measurement is not possible -for construction or for cost reasons-, a measurement of the beam-gas lifetime is a very efficient way to have an early warning for a possible leak, difficult to diagnose by conventional means.

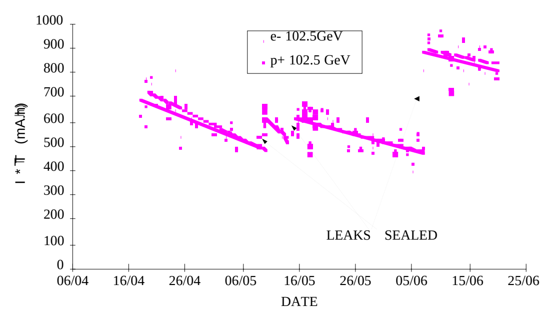


Figure 2: The product $I*\tau$ at 102.5 GeV during the year 2000

3 VARIATION OF PRESSURE WITH BEAM ENERGY

The desorption generated by the synchrotron radiation induces a pressure increase in LEP proportional to the beam intensity[2]. The pressure increase per unit beam current is called the dynamic pressure (D.P.). This D.P. has been measured in various places in LEP at different beam energies. The variation of energy during LEP filling and the change in bending radius in some places like the injection regions give rise to photon energy spectra with critical energies between 7.6 keV and 1.5 MeV[3]. The

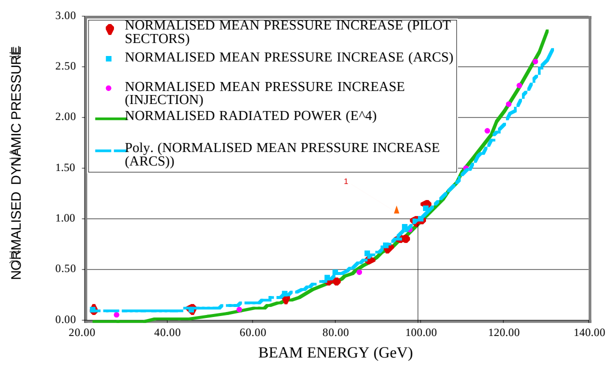


Figure 3: The evolution of the dynamic pressure with beam energy

corresponding D.P. were recorded for more than 40 gauges and their average calculated. This average was normalised to 1 for E_b=100 GeV. The results are displayed for 3 categories in Figure 3 as a function of the beam energy (E_b) or its equivalent[3] for the injection regions. On the same graph, the normalised synchrotron radiated power and the best fit to the normalised mean D.P. for the LEP arcs is also given. For beam energies exceeding 50 GeV, (critical energy greater than 100 keV) the molecular desorption is proportional to the radiated synchrotron power.

4 EVOLUTION OF DYNAMIC PRESSURE WITH BEAM DOSE

In the LEP arcs three pilot sectors have been equipped, during construction, with calibrated Bayard-Alpert gauges. The evolution of the dynamic pressure in these sectors has been recorded throughout the years and is plotted as a function of the accumulated beam dose (mA.h) on Figure 4 since the start of the LEP operation in 1989. The initial pressure increase[4] was higher than 10^{-5} Pa at 45 GeV

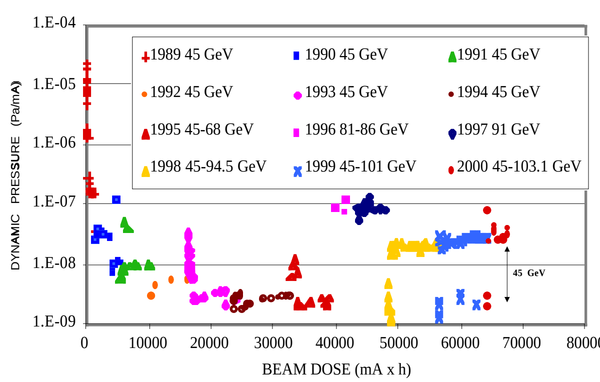


Figure 4: The dynamic pressure evolution in LEP arcs since 1989

and very quickly decreased by more than 3 orders of magnitude within the same year. The pressure evolution does not show a steady decrease but distinct steps due to the reactivation of the non evaporable getter pumps (N.E.G.)[5] followed by a steady increase of the pressure

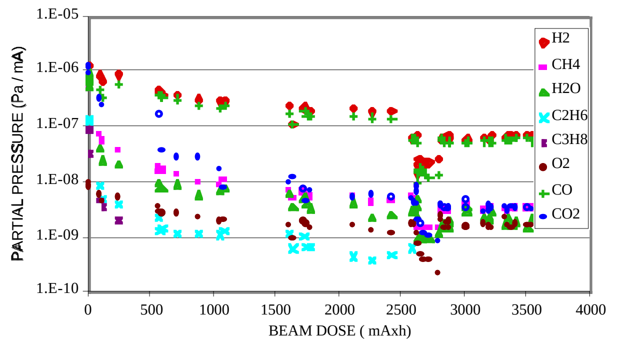


Figure 5: The variation of the gas composition during the cleaning of a new aluminum chamber

due to its saturation by the desorbed gas. After a dose of 17000 mA*h, i.e. 4 years of operation the D.P. measured at 45 GeV stabilized close to $2*10^{-9}$ Pa/mA and has remained constant until now. The operation at higher energy has caused an initial jump in pressure by more than a factor of 10. The evolution of the D.P. along one year does not show any cleaning effect but a slight increase due to the saturation of the NEG ribbon superimposed to that provoked by the gradual beam energy increase during the year. The present D.P.

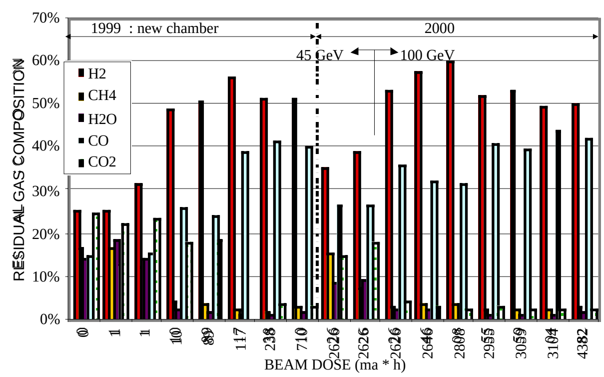


Figure 6: The gas composition variation with the beam dose

measured at 103 GeV in the arcs is $3x10^{-8}$Pa/mA.

The variation of the residual gas composition during the cleaning of an aluminum LEP chamber has been studied in situ by measuring the gas composition with a remotely controlled residual gas analyser during the years 1999 and 2000. The partial pressure measured are shown in figure 5 and the corresponding percentage in figure 6. During the initial part of the cleaning the main gases are H_2, CO_2, CO, CH_4 and H_2O (although the system was initially baked)with concentration between 10 and 25 %. As the cleaning evolves, H_2 and CO become the leading gases (>90%). After the winter shut down (the sector was not exposed to air), the initial gas composition changed and the relative percentage of CH_4, H_2O and CO_2 became temporarily close to 10%. A fast cleaning at 45 GeV reestablished a high H_2 content (more than 60%) with 30% of CO. The energy was then raised above 100 GeV resulting in an increase of the CO partial pressure and a final composition with 50% H_2 and 43% CO.

5 STATISTICS OF LEAKS DURING LEP OPERATION

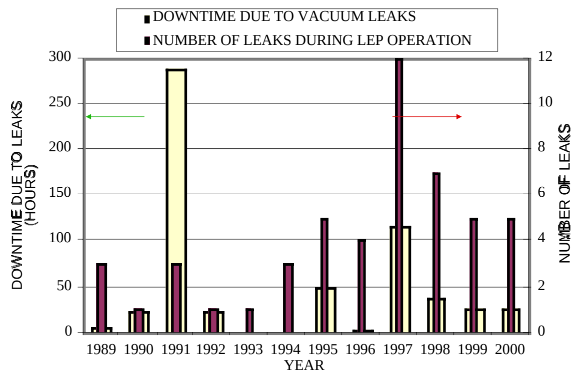
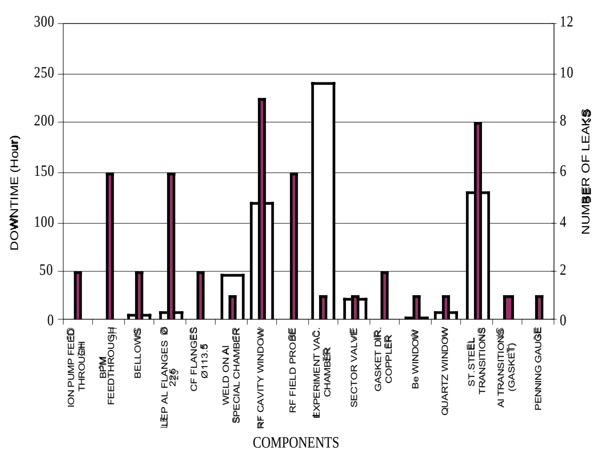


Figure 7 Number of leaks and downtime during LEP operation

After more than 10 years of steady operation and an energy upgrade program from the design value 86 GeVto more than 100 GeV, the LEP vacuum system has been exposed to very stringent operating conditions. Despite a rigorous control of the tightness of the many components (for example more than 7000 feedthroughs and more than 13000 aluminium gaskets) before and after their installation, several leaks occurred during LEP operation.



The figure 7 presents the number of leaks which were noticed during the LEP running period, some of them stopping the accelerator. The largest downtime was experienced in 1991 with a leak on a carbon fiber vacuum chamber which needed a partial dismounting of the detector to be repaired. In 1997,while the energy was increased above 90 GeV, ten leaks occurred on stainless steel components which were inappropriately cooled. Most of these failures were due to an inhomogeneous heating of Conflat® gaskets. Figure 8 shows the downtime and the number of failures against the component type. Apart from the experimental chamber, the radio frequency windows and the stainless steel transitions between elliptical and circular vacuum chambers caused the largest number of interventions. The averaged number of leak is 4 per year with a mean downtime of 30 hours per year (the experimental chamber excluded)

6 CONCLUSIONS

After eleven years of running, LEP will be dismounted in October 2000. Beside its unique main pumping system (a 20 km long NEG getter ribbon), LEP is also the only accelerator where the vacuum chambers are exposed to synchrotron radiation photons with energies above 1 MeV. As a consequence of this the photon induced desorption could be investigated at these very high photon energy revealing a direct proportionality between the radiated power and the desorbed gas flux. The cleaning effect of this desorption could be studied for high radiation dose showing a saturation of the cleaning above 17000 mA*h. The observation of the I*τ variation has proven to be a useful method for an early detection of leaks before they may stop the operation of the accelerator. This method together with a careful procedure of leak testing has contributed to the good overall reliability of the LEP vacuum system.

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