THE BEHAVIOUR OF THE SYNCHROTRON RADIATION INDUCED GAS DESORPTION DURING THE FIRST RUNNING PERIOD OF LEP

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Abstract: The behaviour of the dynamic pressure in LEP during the first months of operation is described and compared with es timates based on desorption measurements made on vacuum chambers which have been exposed to synchrotron radiation in a dedicated beam line on the DCI storage ring in Orsay. The data of the observed beam cleaning of the LEP vacuum system as a function of the integrated photon dose and the resulting beam lifetime from beam-gas interaction are presented.

Introduction

The vacuum system of LEP has been described in detail previously [1,2] In this paper the dynamic pressure behaviour due to the synchrotron radiation in the bending magnets will be reported. The regular lattice in the bending arcs of LEP represents a total length of close to 23 km where the vacuum chamber is made of extruded aluminium profiles with an elliptic duct for the beam and a lateral channel for the linear NEG pump connected by a single row of oblong pumping slots. Three cooling water ducts are provided to evacuate the power deposited by the synchrotron radiation and by the NEG ribbon during the activation and reconditioning. For reasons of magnet aperture, the lateral NEG pumping channel has been suppressed on the short (about 3.6 m long) vacuum chambers for the quadrupole and sextupole magnets. These chambers rely on the pumping from both ends. The pumping system uses the combination of a linear NEG ribbon and of small (40 l/s) sputter ion pumps mounted at an average distance of 20 m. For the initial pumpdown, turbomolecular pumps are connected to the system by manually operated valves but are removed from the LEP tunnel during operation.

All vacuum sectors have been baked to 150°C for 24 hours during the installation and commissioning phase of LEP by circulating superheated water in the water ducts of the chambers. During the vacuum commissioning, the NEG pumps are activated by heating with electric current to 750°C. Before the start-up of LEP with beam a static base pressure below 2 10^{-11} Torr has been achieved. Because of the large size and the numbers involved, it has not been possible to equip the whole of the machine with a complete set of remote vacuum monitoring equipment. For detailed studies of the vacuum performance, 3 "pilot sections" of 270 m length have been equipped with UHV vacuum gauges and with quadrupole residual gas analysers which can be operated and recorded from the central control room. In addition, the beam current data are logged continuously and used to normalise the pressure rise (dP/di) to the beam intensity and to compute the integrated beam dose - expressed as the product of mA hours and as the total number of accumulated photons/m.

Synchrotron radiation induced desorption of LEP vacuum chambers

The photon induced desorption rate of the LEP vacuum chambers has been measured at several stages during the series production by exposing finished chambers to synchrotron radiation in a dedicated beam line at the DCI storage ring of the LURE laboratory in Orsay. A detailed description of the measuring setup used for these studies and of the results has already been published [3,4]. One of the aims has been to simulate as closely as possible the conditions in LEP at injection energy. The DCI machine could be operated with a critical energy of 3 keV, a grazing angle of incidence of the photons on the vacuum chamber of 11 mrad and a flux of up to10^{17} photons/second/m of chamber. For comparison, the critical photon energy at injection into LEP is about 6 keV and the grazing angle of incidence on the vacuum chamber about 7 mrad. The linear photon flux at injection energy in LEP is 8 10^{14} photons/m/mA - i.e.1 Ahour is equivalent to a dose of 3 10^{21} photons/m.

The photon stimulated outgassing rate of the LEP vacuum chamber measured at DCI [5] is shown in Fig. 1. The molecular species desorbed in significant quantities are H_2, CO and CO_2 and CH_4. For all gas species a large cleanup factor is obtained within the period of exposure which corresponds to approximately 1 Ahour in LEP. The lower desorption yield of CH_4, as compared to CO and CO_2, but mainly its fast clean-up during photon exposure have provided the main justification for installing a relatively low effective ion pump speed in LEP of only about 1 l/s/m.

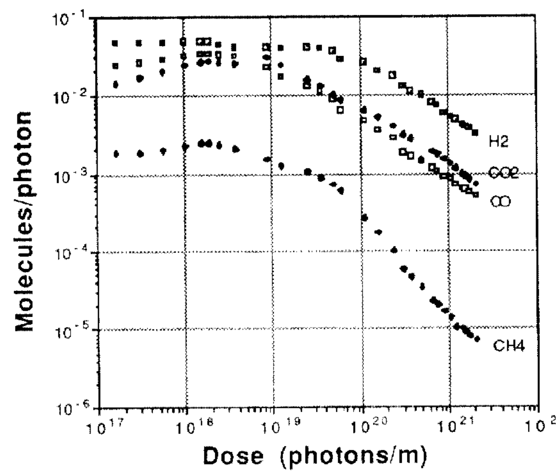

Fig. 1 : Molecular desorption yield η (molecules/photon) as a function of the integrated number of photons for a LEP vacuum chamber measured at DCI.

From the data from DCI shown in Fig. 1 the total amount of gas desorbed during the LEP beam cleaning process has been calculated and has been used to evaluate the amount of CO and CO_2 pumped by the NEG as a function of the accumulated beam dose. This gas load determines the rate of decrease of the pumping speed and the intervals at which the NEG pumps have to be reconditioned. Figure 2 shows the integrated quantities of desorbed H_2, CO and CO_2 as a function of the dose in photons/m. The arrows refer to the reconditioning of the NEG pumps.

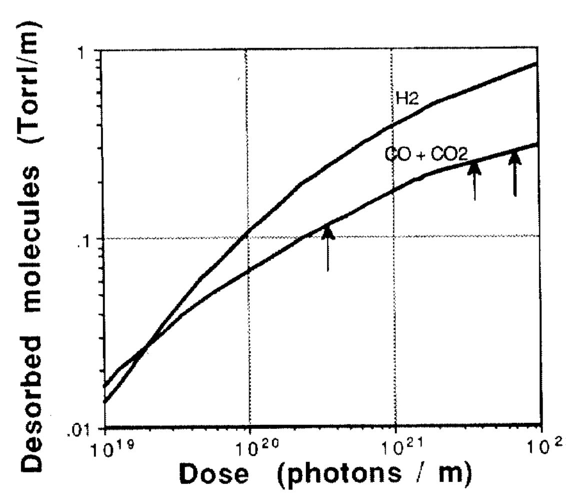

Fig. 2. : Integral of the desorbed quantities of H_2 and of the sum of $CO+CO_2$ as a function of the photon dose derived from Fig. 1. The arrows refer to 3 NEG reconditioning cycles.

Pumping system for LEP

The effective linear pumping speed in LEP is a strong function of the gas species and because of the NEG characteristics, decreases with the adsorbed quantity of gas [6]. The global performance of the LEP pumping system is shown in Fig. 3. It can be seen that the effective pumping speed available in the beam channel is reduced by the vacuum conductance of the pumping slots in the separation wall to the pumping duct. For inert gases, - mainly CH_4 and Ar - a low but constant pumping speed of about 1 l/s/m is maintained by the lumped ion pumps. During LEP operation, the NEG may be reconditioned either, when the global pumping speed has dropped to some predetermined lower limit, - 30 l/sm has been proposed - or at a convenient occasion at the end of a long machine stop.

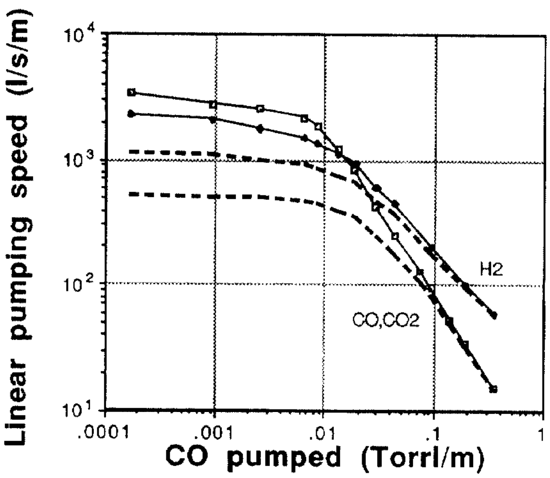

Fig. 3. : Linear NEG pumping speed in LEP for H_2 and CO (CO_2) as a function of the sorbed quantity of CO. The dashed curves represent the effective pumping speed in the beam channel due to the conductance of the pumping slots.

Since the start-up of LEP in July 1989, the NEG pumps have been reconditioned 3 times. Of these 3 reconditioning cycles identified by the arrows in Fig. 2, the first 2 were performed because of the gradual saturation of the NEG after pumping CO+CO2 for a total amount of 0.12 and 0.13 Torrl/m respectively and the last reconditioning was made at the end of the first long machine stop in March 1990. In the period from the start of LEP in July 1989 to May 1990, an estimated amount of 0.3 Torrl/m of $CO+CO_2$ and approximately 0.8 Torrl/m of H_2 have been pumped by the NEG.

Dynamic pressure and residual gas composition

The dynamic pressure in the bending arcs of LEP is shown in Fig. 4. The figure gives the total specific pressure rise as a function of the integrated beam dose for 2 pilot sections in LEP, section S213, which is considered representative for the global performance of the vacuum system and for section S276, a sector where the NEG pumps have so far not been reconditioned. The arrows point again to the NEG conditioning cycles. The observed initial dynamic pressure rise - between 1 and 2 10^{-7} Torr/mA - agrees well with the value expected from the desorption yield of the chambers measured at DCI and taking into account the known pumping speed for the different gas species. It should be born in mind, that the global beam cleaning effect represented in Fig. 4 reflects the combined effects of the gradual cleaning of the vacuum chamber, of the progressively reduced pumping speed of the NEG and of the change in gas composition due to the different cleaning rates of various gas species. This last effect is most pronounced for CH_4. The analysis of the residual gas confirms, that due to the very low pumping speed for CH_4, this gas has been initially the dominant constituent of the dynamic pressure. This gradual change of the gas composition as a function of the beam clean-up from a CH_4 to a $CO+CO_2$ dominated system is illustrated in Fig. 5.

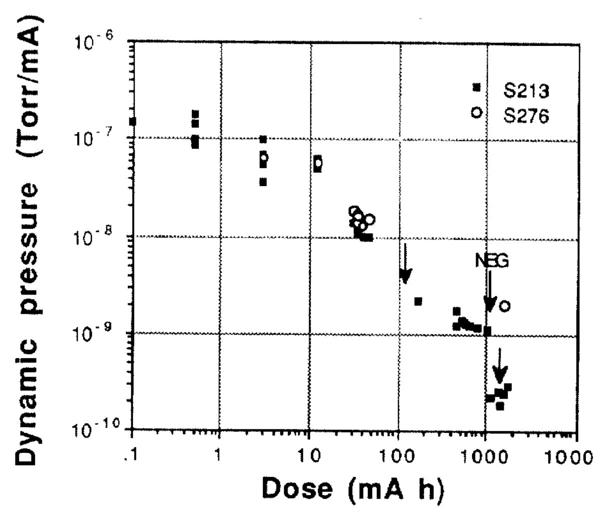

Fig. 4. : Dynamic pressure rise in 2 test sections of LEP as a function of the integrated beam dose. S213 is representative for the arcs of LEP, S276 is a section where the NEG pumps have so far not been reconditioned, hence the linear pumping speed for CO and CO_2 has decreased to less than 15 l/s/m.

A comparison of the dynamic pressures in the two pilot sections S213 and S276 (Fig. 4) shows a difference by a factor of 10 at 2.5 A hours beam dose which can be attributed to the lower pumping speed in S276. Under the assumption that the total gas load is the same in both sections - about 0.3 Torr l/m for $CO+CO_2$ - the remaining pumping speed of the NEG would be in the range of 10 to 15 l/sm.

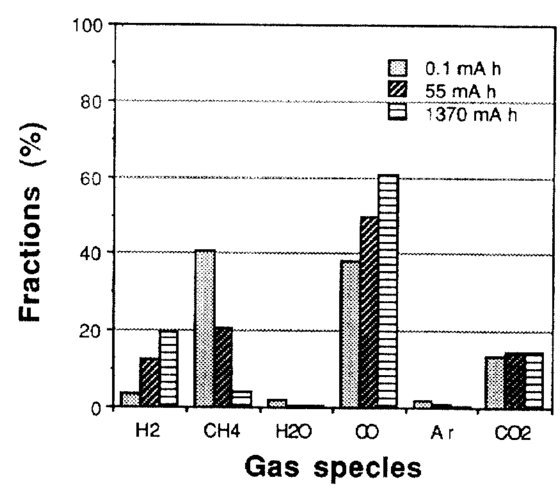

Fig. 5. : Evolution of the residual gas composition in the arc of LEP during the initial period of beam cleaning. Below 30 mAh dose the data were taken at 20 GeV beam energy, for higher dose at 46 GeV.

The increase of the dynamic pressure rise with beam energy from 20 GeV to 46 GeV - above 30 mAh beam dose the data in Fig. 5 refer to 46 GeV - has been found to be approximately a factor of 1.4 as shown in Figure 6. For comparison, based on the model that the gas desorption is proportional to the photoelectron production, the solid curve represents the increase of the photoelectron current which would be expected due to the change of the synchrotron radiation spectrum [7]. In view of the simplified calculation which assumes perpendicular incidence of the photons and neglects any secondary effects like scattering and reflection of photons on the vacuum chamber, more measurements will be necessary to obtain the energy dependence of the dynamic pressure rise and in particular its extrapolation to higher beam enegies in LEP.

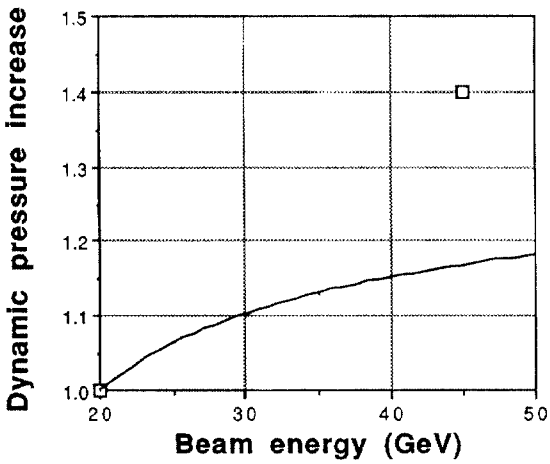

Fig. 6. : Increase of the dynamic pressure rise between 20 GeV and 45 GeV. The curve represents the photoelectron current calculated for the simplified case of perpendicular incidence of the photons.

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Beam-gas lifetime

The average pressure in nTorr for different molecular species equivalent to 1 hour beam gas lifetime in LEP [8] is given in the following table.

H_2	CH_4	H_2O	CO	Ar	CO_2
460	55	42	28	9.5	17.5

These values have been used to calculate the expected beam gas lifetime in LEP from the residual gas spectrum in the pilot section S213. Figure 7 shows how the contribution of the different gas components to the global beam-gas lifetime has changed during the initial beam cleaning period. The lifetime has been normalised to 1 mA total beam current and the assumption has been made, that the average pressure in LEP is entirely determined by the bending sections - i.e. the pressure in the synchrotron radiation free straight sections has been neglected. During the first months of LEP operation, the calculated beam-gas lifetime, derived from the vacuum measurements, and the actually observed lifetimes were found to be in agreement to within approximately 30% [9]. With the improvement of the dynamic vacuum to about 2 10^{-10} Torr/mA after 2.5 A hours total beam dose, the beam-gas lifetime in LEP for a 1mA beam has increased to above 100 hours.

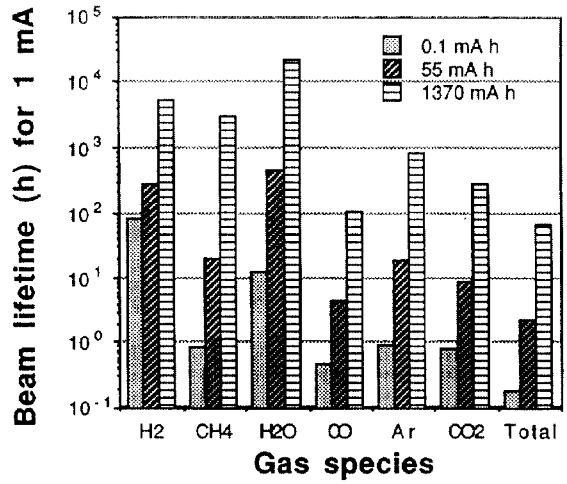

Fig. 7. : Contribution of the residual gas species to the beam-gas lifetime in LEP and its change during the initial period of beam cleaning.

Acknowledgements

The performance of the LEP vacuum system presented here is the result of the common effort of all members of the LEP vacuum group and reflects the global result of a large number of individual and specific contributions in the field of ultra-high vacuum techniques.

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