EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

Large Hadron Collider Project

LHC Project Report

Vacuum Stability for Ion Induced Gas Desorption

I. R. Collins, O. Gröbner, O.B. Malyshev, A. Rossi, P. Strubin and R.Veness

LHC Division

Presented at e^+e^- Factories '99
International Workshop on Performance Improvement of Electron-Positron Collider Particle Factories
21-24 September 1999, KEK, Tsukuba, Japan

Administrative Secretariat
LHC Division
CERN
CH - 1211 Geneva 23
Switzerland

Geneva, 18 October 1999

where σ is the ionisation cross section of the residual gas molecules, P the pressure, e the unit charge and Q_o the thermal outgassing rate from the wall. The balance of molecules desorbed by the beam and removed by external pumps, S_{eff}, can be written as :

$$P S_{eff} = \eta \, \sigma \, \frac{I}{e} P + Q_o$$

and thus the original pressure bump equation

$$P = \frac{Q_o}{S_{eff} - \eta\sigma \frac{I}{e}}$$

was obtained. One finds that the pressure increases with beam current and that above a critical value

$$(\eta I)_{crit} = \frac{e \, S_{eff}}{\sigma}$$

no equilibrium pressure exists. At half this critical value, the initial pressure doubles. This limiting product depends on the effective linear pumping speed ($m^3s^{-1}m^{-1}$) of the vacuum system.

Since the configuration of vacuum chambers and pumps was given, the effective pumping speed in the ISR could be calculated from which in turn, an ion–induced desorption yield could be inferred by observing the maximum current at which the pressure could be maintained stable. It turned out that for the 200˚C baked vacuum chambers η's of between 2 and 4 molecules per ion were deduced. Subsequently, by installing additional pumping (titanium sublimation pumps), special ex–situ glow discharge cleaning and in–situ baking to 300˚C for 24 hours it was possible to increase the critical current product $(\eta I)_{crit}$ and simultaneously to reduce the desorption yield to acceptable levels (η's of close to zero and even negative) such that beam currents of up to 60A could be stored in the ISR.

Over many years an intensive program of measurements was performed on the ISR vacuum system itself using a dedicated vacuum test section, the results of which have been documented in a large number of internal 'ISR-Performance Reports' but with few exceptions [4], have remained largely unpublished. In view of the regained interest in the vacuum performance with recent high intensity machines, in particular the LHC, it seems an appropriate moment to review the main aspects of this work.

2 ION INDUCED PRESSURE INSTABILITY

Until now the ISR has been the only machine which has shown the ion induced pressure instability. For future high intensity machines, particularly for the LHC, the machine parameters are such that this vacuum effect is likely to affect the performance and specifically the maximum stored beam current. For this reason an intensive study has been initiated to identify possible ways of overcoming the vacuum instability in various parts of the ring, mainly in the sections where the vacuum system of the LHC is at room temperature and hence relies on conventional pumps. Parameters which influence vacuum stability will be reviewed in the following sections but the only two quantities which are under the control of the vacuum system designer are the pumping speed (S_{eff}) and the cleanliness of the vacuum system (η).

2.1 Residual gas ionisation

Ionisation cross sections for some common gas species are listed in Table 1. The values have been calculated for the proton beam energies in the ISR and for LHC using the formulae from Ref. [5]. For high energy particles the ionisation cross section depends on the relativistic speed and on the charge rather than on the type of the particle. Hence these cross sections may be used for electrons, protons and also for a beam of relativistic lead ions in the LHC.

Table 1: Ionisation cross sections

	Ionization cross-section (in 10^{-22} m^2)	
Gas	26 GeV	7000 GeV
H_2	0.22	0.37
He	0.23	0.38
CH_4	1.2	2.1
CO	1.0	1.8
Ar	1.1	2.0
CO_2	1.6	2.8

In addition to the ionisation cross section due to collisions, photo-ionisation of residual gas molecules by synchrotron radiation may become important not only in positron storage rings but also in the LHC machine with its large photon flux. The effect of photo-ionisation has been studied for the PEP-II vacuum system where it was shown that for ions produced close to the beam, this effect may be of the same order of magnitude as the rate of ionisation due to collisions.

2.2 Effective linear pumping speed

The pumping speed which is required to compensate the desorption by ions depends strongly on the configuration of the vacuum system. For a periodically pumped, linear vacuum system the vacuum stability condition can be calculated as shown below [6]. The addition of distributed pumping, e.g. by a continuous, linear getter pump or by