Effect of External Magnetic Field and Radiation upon the Accuracy of Total and Partial Pressure Measurements

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Abstract

Cold cathode discharge gauges use crossed electric and magnetic field. The slope of the gauge current versus pressure characteristic curve on a log-log plot may be steeper at pressures ranging 10^{-9} - 10^{-10} mbar and the pressure reading strongly depends on the applied magnetic field. The trajectory of ions in the quadrupole mass filter is also influenced by strong external magnetic fields (~ 100 Gauss) by altering the spiral path. These undesired side effects can occur particularly if the cold cathode gauges and quadrupole mass spectrometer heads are situated too close to bending magnets in the storage ring. Secondary electrons can be generated if radiation strikes the tubes used to mount gauges and analyser heads. Readings from the gauges and mass spectrometer heads can be affected by the creation of extra ions. In the Elettra storage ring all above mentioned vacuum instruments had to be installed (due to spatial problems) in places where there is a strong external magnetic field (~ 1000 Gauss) and also the radiation reflected from the photon absorber is not negligible. In some cases the simple µ-metal shielding was not adequate. Suitable modification of vacuum component mounting and correction of pressure readings has led to more reliable total and partial pressure measurements.

1. INTRODUCTION

In the third generation synchrotron light source Elettra magnetic fields of dipole, quadrupole, sextupole and insertion device (undulators and wigglers) magnets are used. Ultra high vacuum conditions are necessary to maintain a good beam lifetime and to have also a short pumpdown after venting.

To check the total pressure around the whole ring Penning gauges are used. Cold cathode gauges were chosen for a negligible outgassing, simple maintanance, low contamination in oil-free systems, reliable interface with computer and acceptable costs. In totaly 46 gauges are installed in the storage ring, 24 of them are mounted in the bending magnet (BM) vacuum chamber close to the frontend valve, another 19 gauges monitor the pressure in the rhomboidal electron beam vacuum chamber, 3 gauges are positioned in the septum tank.

Due to spatial problems, 5 of vacuum gauges installed in the electron beam chamber had to be mounted at the edge of the dipole magnets - the distance between the magnet and the gauge's magnet is only 12 mm. The magnetic fields are not parallel, the mutual angle varies between 30 and 50 degrees.

Six quadrupole mass analyzer (QMA) heads are uniformly distributed around the ring to check partial pressures of residual gases, to monitor outgassing of the internal walls during the bake-out procedure in situ and to analyse the composition of desorbed species when the radiation hits the surface. Due to similar problems with the available space for installing all necessary components on the BM vacuum chamber (photon beam shutter, cold cathode gauge, manual valve for roughing pumps, NEG cartridge flange), QMA heads could be mounted only in the place where the accuracy of measurements can be disturbed by the external magnetic field formed by dipole and partially also by quadrupole magnets.

Another source of parasitic magnetic fields are created by insertion device (ID) magnets - undulators and wigglers. The ID vacuum chamber is a 4.8 m long tube with an elliptical cross section connected via slots with the cylindrical ante-chamber. The whole ID system is pumped by four sputter-ion pumps (SIPs), two are at the ends, two separated by a distance of 1.6 m. Three Penning gauges can be installed midway between two pumps. This arrangement allows the pressure profile in the ID chamber at different beam currents and different gaps yo be verified.

The accuracy of total and partial pressure measurements can be affected not only by strong external magnetic fields but also the radiation can give rise to a number of problems. On a circular machine, the synchrotron radiation is emitted tangentially outwards and the plastic sheets of the connecting cables can become hardened and brittle due to radiation effects. Some electronics (such as the junctions of transistors) can be affected by radiation, too. These hardware problems can be avoided by keeping the cables and electronics in metal enclosures. In our case the electronic part of QMA (RF, amplifiers) is mounted outside the tunnel where the effect of radiation is negligible.

A more complicated problem can occur if radiation strikes the tube used to mount an analyser. This can also affect the results from the QMA by creating extra ions in the ion source. A similar effect can be observed if the ionisation gauge is mounted closely to the photon absorber. Photoelectrons and characteristic radiation of the copper can misinterpret both total and partial pressure measurements.

2. RESULTS AND DISCUSSION

The following data were obtained on the Elettra storage ring, which has a stainless steel vacuum chamber. The whole ring was baked in situ at 150 °C, the pressure after 20 Ah of conditioning was kept in the low 10^{-10} mbar range. The external magnetic field strength was measured by gaussmeter in places where cold cathode gauges and quadrupole mass analyzer heads are mounted. The magnetic field strength depends on the magnet currents which is changed according to the desired electron energy in the range 1.1 ÷ 2 GeV.

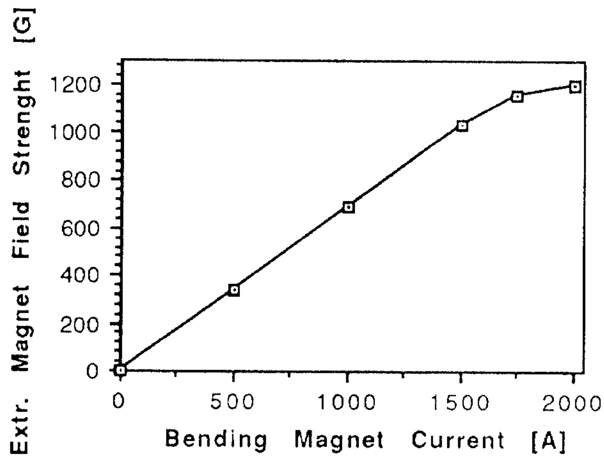

Figure 1. Magnetic field strength vs. bending magnet current

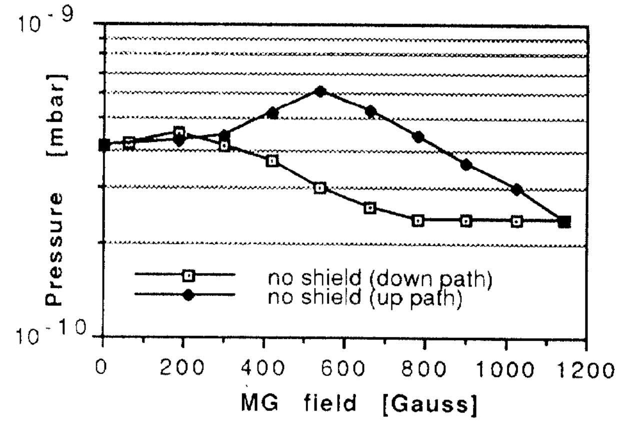

Figure 2. Pressure vs. magnetic field changes for PGII

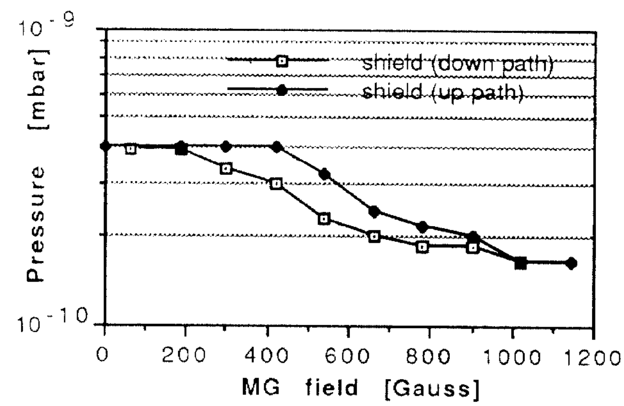

Figure 3. Pressure vs. magnetic field changes for PGIII

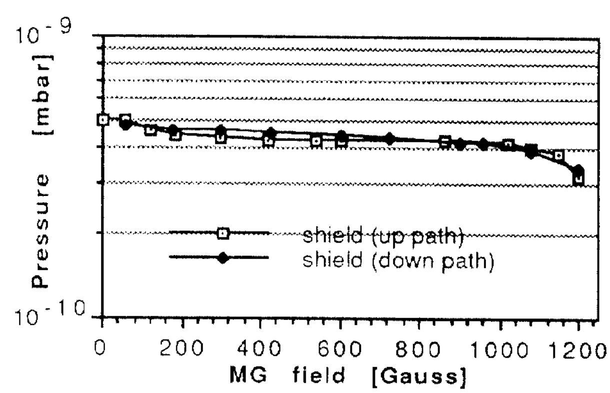

Figure 4. Pressure vs. magnetic field changes for PGIV

The gauges were of the inverted magnetron type IKR 020 connected with triaxial cables and powered by TPG 300 supplies. The self magnetic field was 1440 Gauss. For this type of gauge the discharge current I is related to the pressure P by the expression

$$I = K P^n$$

where K and n are gauge constants. There are no data in the literature about the correlation between magnetic field strength and the values of constants, only some predictions can be found.

Jepsen [1] supposed that the current would increase with increasing field, reaching a maximum and then decrease when the electrons could not attain sufficient energy to ionize the gas. Nichiporovich [2] found that the gauge current increased rapidly with the magnetic field of about 1600 gauss then remained virtually constant and around 4000 Gauss he found a slight decrease in current.

In our experiment we were only qualitatively able to evaluate how the increasing magnetic field can change pressure readings. Four cold cathode gauges measuring the pressure in the electron beam chamber were continuously monitored. One of these gauges (PGI) was installed outside of the magnetic field influence, another three gauges had the same position with respect to the bending magnet, one of them (PGII) had no shielding, (PGIII) was shielded with μ-metal foil, the last (PGIV) was shielded with special shielding developed by Balzers. At zero magnet current the pressure readings of all four gauges varied from 3.6×10^{-10} mbar to 4.2×10^{-10} mbar. Then the magnet current has increased up to 2000 A (up path) and consequently decreased (down path) to have the possibility to observe any hysteresis effects. Results are presented in fig. 2, 3, and 4, the pressure reading of PGI was not changed.

It seems that our results are in disagreement with respect to the above mentioned predictions. The measurements are very reproducibile and the hysteresis is evident. The μ-metal shielding is not sufficient, at the magnetic field strength over 400 Gauss the foil was saturated. The Balzers shielding is appropriate and for all gauges working under external magnetic field up to about 1200 Gauss can be successfully used.

Similar measurements were made on quadrupole mass analyzer heads on which linearity, sensitivity and stability tests were performed in our previous work [3]. The magnetic field strengths are different for two positions of the heads with respect to the type of bending magnet vacuum chamber with either a BM or ID radiation exit port. In the case of the bending magnet port the magnetic field increases from 0 to 200 Gauss and the sensitivity of the quadrupole mass spectrometer drastically decreases - fig. 5. In the case of the insertion device port the magnetic field increases up to 1200 Gauss and the sensitivity falls to zero immediatelly.

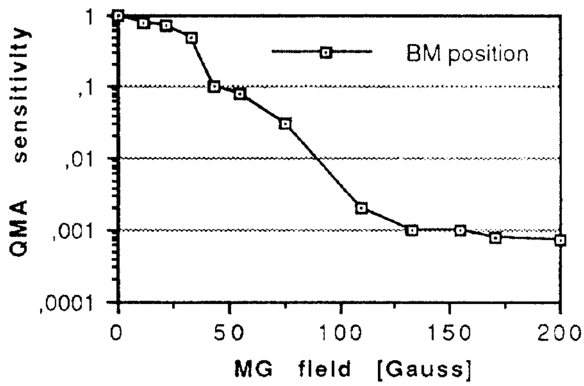

Figure 5. Sensitivity of QMA at increasing MG field

The sensitivity decrease is in practice the same for masses up to 50, higher masses do not occur in our storage ring. Linearity tests could not be done because there is no possibility to increase regularly the pressure in the vacuum chamber. No appropriate shielding has been found for the quadrupole mass heads due to the mentioned spatial problems, moreover, a large shielding could create problems with the beam orbit.

During all commissioning runs one very particular effect has been observed. The pressure in the storage ring without beam was quite uniform in all vacuum sectors in the 10^{-10} mbar pressure range. When the beam was present the pressure in all insertion device bending magnet sections named as S_X.2 (X = 1 ÷ 11) was 10^2-10^3 times higher than in the dipole BM sections named as S_X.1 (X = 1 ÷ 12). This effect was pronounced also at relatively low beam currents. From the design of the ID BM vacuum chamber it is clear that the Penning gauge (VGPEB) is - due to spatial problems - installed close to the photon absorber (PA) compared to the gauges of the dipole BM vacuum chamber. In our opinion this enormous pressure increase could be caused by i) a huge amount of desorbed particles from the copper photon absorber, ii) the increased ionization caused by radiation.

To distinguish between these two possibilities the pressure at different beam currents was measured - see fig. 6. The pressure decrease after longer conditioning time (a higher dose) is evident in the case of S_X.1 gauges. On the other hand the average pressure of all gauges S_X.2 is in practice constant and does not depend on the dose. It probably means that the rapid pressure increase (also at very low beam currents, lower than 1 mA) is due to radiation. In one section (S_2.2) a "T" piece was installed over the PA. Here the PEGs can be installed at different positions, where the radion should not disturb pressure measurements.

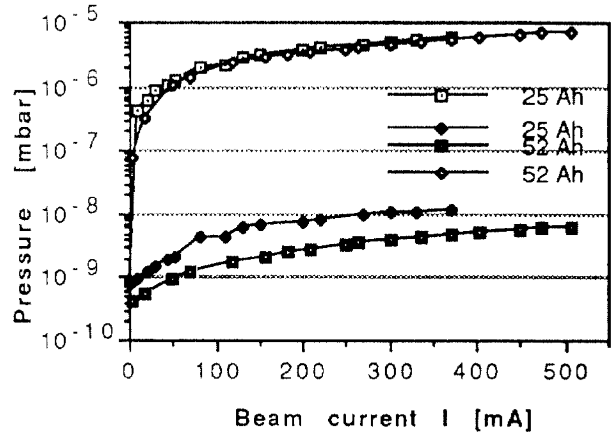

Figure 6. Pressure after different dose
(S_X.2 gauges - upper curves, S_X.1 gauges - lower curves)

According to obtained results we are now sure that these high pressure values do not correspond to the real pressure. The reasons are following: the ID BM vacuum gauge is installed over the photon absorber. When the synchrotron radiation hits the copper surface the two main elementary processes can occur: i) formation of photoelectrons, ii) emission of the copper characteristic radiation with the wavelength of 13.336 Å (L_α), 12.122 Å (L_β) and partially also of 1.54 Å (K_α). The corresponding energies are 0.93 keV, 1.02 keV and 8.047 keV. Both processes increase the ionization probability of residual gases and lead to rapid increase of ion current which is proportional to the total pressure.

To inhibit this effect it is necessary to install the gauge through an elbow or to increase the distance between the copper absorber and the gauge, then these effects are atenuated. Another possibility of shielding, the grid at proper potential will be studied in future.

3. CONCLUSIONS

From the presented results it is clear that many vacuum measurements can be affected by magnetic fields or by radiation. The position of the vacuum and QMA gauges is extremely important as well as an appropriate shielding of vacuum heads.

4. REFERENCES

[1] R. L. Jepsen, J. Appl. Phys. 32, 2619 (1961)

[2] G. A. Nichiporovich, Prib. Tekh. Eksp. (5) 186 (1966) [Instrum. Exp. Tech. (USSR) 5, 1215 (1967)]

[3] J. Miertusova, F. Daclon, F. Pradal, "Comparative Test of Small QMA, Sincrotrone Trieste", ST/M - 93/1, 1993

[4] J. Miertusova, F. Giacuzzo, F. Daclon, "Experience with Elettra Vacuum System", this conference, EPAC'94