Experience with the Elettra Vacuum System during Commissioning

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Abstract

Elettra is a third generation synchrotron light source which has been built especially for the use of high brilliance radiation from insertion devices and bending magnets. The vacuum system presents some pecularities which cannot be found in any existing machine. Carefully performed cleaning and outgassing procedures brought the base pressure to the 10^{-10} mbar range even for the unbaked vacuum chamber. A microprocessor controlled bakeout system developed in our laboratory was succesfully tested during commissioning. After in situ baking at the uniform temperature of 150 °C the specific outgassing rate of $2x10^{-13}$ Torr.l.sec^{-1}.cm^{-2} was obtained. The analysis of residual gas mixtures and bakeout monitoring were performed by multiplexing 6 quadrupole mass spectrometers. The control system for sputter-ion pumps (SIP) was developed in house. This enables to power 2 + 7 SIPs with only one power unit. There is a possibility of reading the absorbed current of each pump and to perform an automatic current to pressure conversion. This system was calibrated up to $5x10^{-11}$ mbar for different SIP types modified with NEG modules. The Elettra vacuum system met all desired specifications after about 100 Ah of conditioning.

1. INTRODUCTION

The assembly of the third generation light source Elettra started in 1992. Elettra vacuum system is described in detail in ref [1]. The transfer line was completed in January 1993. After 48 hours of pumping an average pressure in the low 10^{-8} mbar pressure range was achieved.

In May 1993 the assembly of the storage ring (SR) started and was finished in September 1993. Mounting of all vacuum chamber components was carefully performed under a plastic canopy, in which an overpressure of dry air was maintaned.

The first injection of the electron beam in the partially completed ring - only the first vacuum sector was ready in June 1993 with an average pressure of $8x10^{-9}$ mbar - was facing some difficulties, since the septum tank was not well outgassed. Due to small conductance in the coil return channel the pressure profile drastically increased when the magnets were powered and a strong discharge was created. The magnet was subsequently dismantled and modifications made to increase the conductance; no further problems of this type were then experienced.

For the initial pumpdown of the storage ring vacuum chamber turbomolecular pumps were connected to each vacuum sector in turn by manualy operated valves but they have been removed from the tunnel during operation. All sputter-ion pumps (SIPs) in each vacuum sector were baked at a temperature of 220 °C and subsequently ST 707 NEG modules installed in the SIP body were partially activated. After 12 hours of SIPs baking the total pressure in each separated sector decreased to the high 10^{-8} mbar pressure range before cooling.

At the beginning of the first commissioning run the bake-out procedure was partially performed only in the third vacuum sector to be in accordance with the time schedule of assembly. In this sector a pressure in the 10^{-10} mbar range was obtained without NEGs activation, which corresponds to a specific outgassing rate of $5x10^{-13}$ torr.l/s (nitrogen equivalent). In the other sectors the pressure varied from $2x10^{-9}$ mbar to $2x10^{-8}$ mbar.

The septum tank which is pumped by two 900 l/s SIPs, was also carefully baked at 180 °C for 50 hours in a special oven. After the complete bake-out which took about 120 hours, the final pressure of $3x10^{-10}$ mbar was reached when the magnets were not powered.

When all vacuum valves (sector, RF and ID) were opened the average pressure of $5.2x10^{-9}$ mbar was stabilized in the storage ring, and an average pressure of $1.5x10^{-8}$ mbar was kept in the transfer line.

During injection the pressure in the septum tank never exceeded $3x10^{-8}$ mbar, which confirmed our theoretical simulation of the pressure profile in the septum tank - fig. 1 - where both extremes (low and high outgassing) are presented.

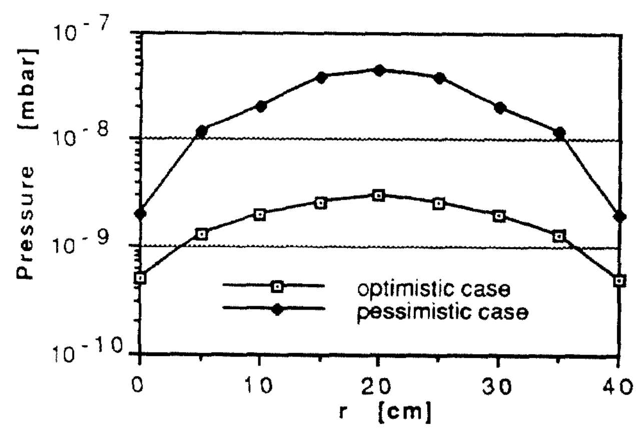

Figure 1. Pressure profiles in the septum tank

Monitoring of the partial pressure of residual gases was performed by multiplexing 6 mass spectrometer heads which are uniformly distributedaround the SR. Due to some problems with the RF and with shielding of the QMAs (quadrupole mass analyzer), the data were obtained only from one analyzer (S_6.1) during the first commissioning run. In the residual gas spectra scanned at different beam currents the masses 2 (H_2^+), 16 (CH_4^+), 18 (H_2O^+, 28 (CO^+) and 44 (CO_2^+) were dominant as it is typical for the unbaked vacuum systems. The mass 30 (NO^+) - fragment ion of HNO3 - was observed at the beginning of the commissioning. Nitric acid could be constantly produced by the reaction of photons with moisture in the air. The production is enhanced by the high voltage at the ion pump feedthroughs which could cause corrosion of the braising. But in the well baked vacuum system the water trace content (mass 18) is negligible which leads to the significant decrease of HNO_3 production.

2 VACUUM PERFORMANCE

During all commissioning runs one very particular effect has been observed. The pressure in the storage ring without the beam was quite uniform in all vacuum sectors, in the 10^{-10} mbar pressure range. But with beam, the pressure in all bending magnet vacuum chambers following an insertion device (named as S_X.2) was 10^2 - 10^3 times higher than in the other bending magnets (S_X.1, X=1÷11) - see fig. 2.

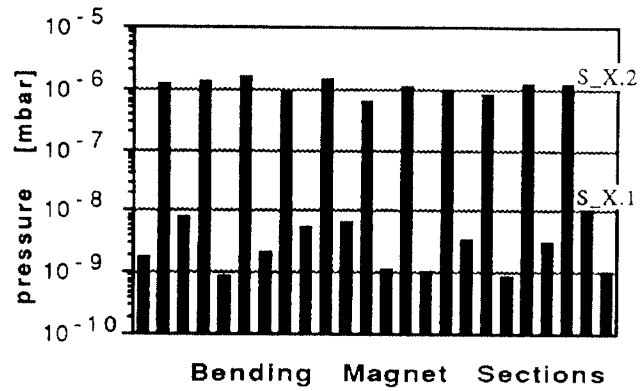

Figure 2. Pressures in BM vacuum chambers at 60 mA

This effect was pronounced also at relatively low beam currents (< 1 mA). From the design of the ID+BM vacuum chamber it is clear that the Penning gauge is - due to spatial problems - installed very close to the photon absorber (PA) as compared to those of the other chambers. In our opinion this enormous pressure increase could be caused by i) a huge amount of desorbed particles from the copper photon absorber, ii) an increasing probability of ionization due to radiation. Very similar effect was observed also in the electron beam vacuum chamber. All cold cathode gauges installed over the top of PA indicate ~100 times higher pressure than gauges installed near to the bottom of the rhomboidal electron chamber - see fig. 3. These effects were studied more deeply, details can be found in ref. [2]. Now we are sure that such anomalous pressure increase does not correspond to the real pressure and can be suppressed by suitable modifications in installation of gauges.

During the run #6 the start-up of the machine proved to be very difficult. Accumulation was found to be very sensitive to the shape of the closed orbit. Various measurements were made which at the end proved conclusively that there was a physical restriction on the inside of the ring, close to the RF cavity. Our original suspicion was directed to the RF shielding of the bellows, which were known to have caused problems at the ESRF. A radiogram of the bellow was carried out, but no destruction or malfunction could be detected. In a further radiogram of the RF cavity valve a definite large restriction of the aperture was seen.

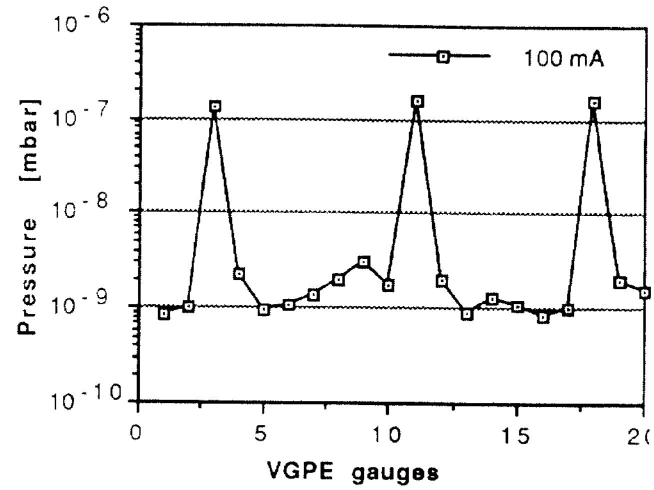

Figure 3. Pressure profile in the electron beam chamber

In the following shutdown the actual fault was found to be the RF shielding of a gasket that is used on either side of the valve. Then all cavity valves around the ring were inspected using an endoscope, entering through a small flange on the RF cavity. Other gaskets were found to be faulty in corresponding locations, causing minor aperture reductions. All faulty gaskets have been replaced during the shutdown and up to now no similar hardware problems occured.

A special attention was paid to pressure monitoring in the insertion device vacuum chamber. The ID vacuum chamber is 4.8 m long and has an elliptical cross-section. The pressure profile can be checked by 3 cold cathode gauges uniformly distributed among four 120 l/s SIP. Bake-out in situ was made for 48 hours at a temperature of 150°C, the base pressure without the beam is in the low 10^{-10} mbar pressure range. Closing the ID gap from 100 to 26 mm at the stored beam of 12 mA, a pressure increase from $2x10^{-10}$ mbar to $8x10^{-10}$ mbar occured. Partially the external magnetic field of the wiggler can cause this effect. Anyway, the pressure increase remained also when the gauge was shielded and was accompanied by the beam lifetime decrease - fig. 4. The pressure increase has been monitored close to the photon beam exit and might have been caused by desorption effect of the enhanced intensity. For interpretation of the lifetime reduction, also the nonlinear effects of the insertion device have to be taken into account.

Bake-out procedure has been performed in each vacuum sector during various shutdown periods. It is difficult to make some conclusions about its efficiency, because always after cooling some leaks were found, especially on the beam position monitor (BPM) rhomboidal flanges. Similar failures were caused also by conditioning of the vacuum chamber at 220 mA and 2 GeV. The thermal load increased the temperature of some parts of the chamber by 20 °C. Leaks in BPM flanges occured due to thermal stress and the pressure increased up to 10^{-7} mbar range. Special fixing of BPMs were performed and also all SIPs supports have been lubricated.

Pumping system and pressure readings according to the current absorbed in the SIP (see ref. [3]) worked reliably. The expressions for pressure calculations have been modified as follows:

$$I = 1590\ P^{1.06}\ (120\ l/s;\ 3\&5\ kV)$$

$$I = 1200\ P^{0.99}\ (400\ l/s; 3\&5\ kV)$$

We would like to point out that the accuracy of pressure readings depends very much on the status of each pump, i.e. if the NEG is saturated or activated (passively or resistively), if the pump electrodes are contaminated or if the pump body is well outgassed.. More details can be found in ref. [3].

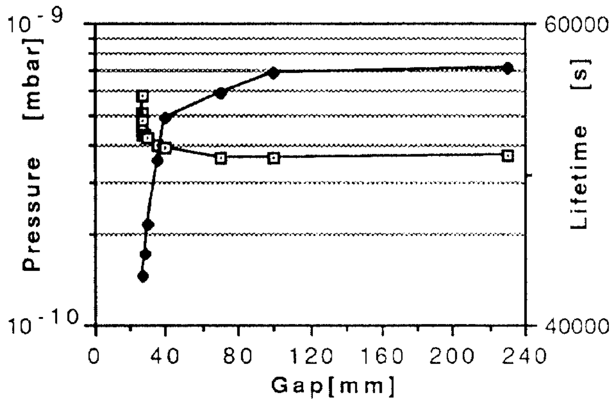

Figure 4. Lifetime and pressure vs. wiggler gap

3. EFFECT OF EXTERNAL MAGNETIC FIELD

Total and partial pressure measurements were strongly affected by the external magnetic field formed especially by bending magnets and partially also by the ID magnets. The cold cathode gauge pressure readings (some gauges are installed 12 mm from the edge of the bending magnet) were disturbed by increasing magnetic field. The magnetic field strength depends on the bending magnet current which varies with the electron energy (from 770 to 1440 A for 1.1 to 2 GeV, respectively). Balzers (producer of our cold cathode gauges) has developed special shielding for Penning gauges which was successfully tested during commissioning.

The simple μ-metal shielding was also tested, but in a magnetic field of over 400 Gauss the foil was saturated and the shielding was not effective.

The quadrupole mass analyzer heads are uniformly distributed around the SR, three of them are positioned in the dipole BM vacuum chamber, another three heads are in the ID BM chamber. Magnetic field strengths vary from 150 to 1500 Gauss at the maximum bending magnet current of 2000 A. The sensitivity of quadrupole heads drastically decreases with increasing MG field. In the case of the insertion device port the magnetic field increases rapidly and the sensitivity falls to zero immadiately. More details about effect of magnetic field on the accuracy of total and partial pressure measurements can be found in ref. [2].

4. CONCLUSIONS

In this paper we tried to interpret main effects observed during commissioning. Investigating the vacuum performance characteristics of Elettra, we can conclude:

1. an ultimate pressure of 4×10^{-10} mbar can be obtained even without NEG activation at 450°C. The residual gas composition is 98% hydrogen, the rest are methane, carbon monoxide and carbon dioxide. At higher currents the CO peak increases (by 30%) and H_2 peak slightly decreases; CO_2 and H_2O contents are at the noise level,
2. the accuracy of the total and partial pressure measurements is strongly affected by external magnetic fields and radiation,
3. the desorption yield η after ~60 Ah of conditioning is 1.5×10^{-6} molecules/photon, the dynamic pressure is in the 10^{-12} mbar pressure range - see fig. 6.

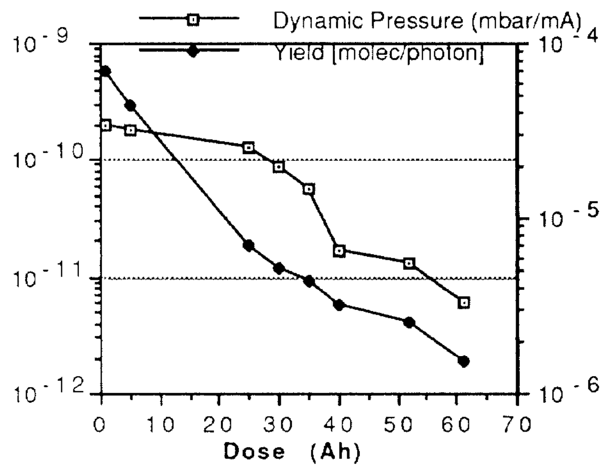

Figure 5. Dynamic pressure and desorption yield at different dose of conditioning

Acknowledgement

The authors would like to thank all colleagues who offered useful suggestions and technical help how to improve the Elettra vacuum system performance.

5 REFERENCES

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