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TWO YEARS OPERATIONAL EXPERIENCE WITH THE PETRA VACUUM SYSTEM

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ABSTRACT

During the first two years of PETRA operation, the vacuum system performance has been analysed to obtain data for the design of future storage rings. According to this analysis, the vacuum requirements on electron storage rings can be more easily attained than commonly expected in the past. PETRA is successfully operating without an in situ bake out or glow discharge cleaning. Further it is shown that low cost Viton sealed gate valves can be unreservedly used and some complicated components, such as electrostatic separators etc., can be built without cooling, since the beam induced mode losses are not locally absorbed. Radiation damage due to Compton-scattered synchrotron light is seen to be a significant problem for high energy storage rings. This calls for a strongly coupled design of vacuum system, magnets and shielding for future electron storage rings.

1. INTRODUCTION

The installation of the 2.3 km long PETRA vacuum system was completed on July 10th, 1978. Five days later, the first electron beam was stored and after only three days of tests it was possible to achieve beam life times of about 2 hours at injection energy. During the following two years of PETRA operation, no vacuum limitations on the machine performance were observed even though the vacuum system was opened several times to install experiments, diagnostic beam components, and additional rf-cavities. Generally, the recovery time for the vacuum in PETRA was very short - about one or two days -, due to the cleaning effect of the synchrotron light. Therefore, it was not necessary to additionally clean the vacuum chambers by bake out or Argon glow discharge, although the PETRA vacuum components are provided with heating elements and discharge electrodes. Only the rf-cavities and some sputter-ion pumps in the experimental regions were baked out in situ.

The vacuum system performance has been studied up to beam energies of 18.3 GeV and much experience, which will be usefull for the design of future storage rings working at still higher energies, was gained.

This paper will present the salient features of the PETRA vacuum system and the performance of the different vacuum componentes during the two years operation. In addition, the performance data will be analysed in view of future electron storage rings working above PETRA energies.

2. PETRA VACUUM SYSTEM

Details of the PETRA vacuum system can be found elsewhere[1,2,3,4]. Here, we will only mention the important features of the design.

The PETRA vacuum system is divided by gate valves into 30 vacuum sections each having a length of about 100 m. This length results from an optimal balance between costs, space requirements, and short pumpdown and leak-detection times. The gate valves are Viton sealed, bakeable up to 150 °C and specially designed in order to reduce the rf-parasitic mode losses[5]. Each vacuum section is provided with a Pirani gauge, a quadrupole mass spectrometer, and a turbomolecular pump. The discharge current of the sputter-ion pumps serve as pressure monitor.

Three different types of vacuum systems exist in PETRA: the vacuum system in the arcs(1800 m total length); the long straight sections for the rf-cavities(360 m total length); and the short straight sections for the experiments(140 m total length).

The standard vacuum chambers in the arcs are made from aluminium extrusions having a four-channel cross section to accept respectively the beam, the integrated sputter- ion pumps, the water cooling and the bake out elements[3]. The standard chambers are produced in lengths of 7.2 m. About 5.3 m of this length lies in the bending field of the magnets and has integrated sputter-ion pumps[3,6]. They have a mean linear pumping speed of 110 l/s/m after bake out, or 60 l/s/m without bake out. Additional 30 l/s holding sputter-ion pumps are installed in the arcs at intervals of about 15 m, in order to hold the vacuum in the ring when the bending magnets are switched off. All the needed aluminium-to-stainless steel vacuum transitions in PETRA are made by two novel techniques developed at DESY[3,7].Each end of a standard vacuum chamber is provided with a stainless steel collar which is used to connect the chambers by in situ welding of a bellow between the collars[3]. The rf "smooth" transition between two chambers is achieved by using rf-finger contacts between the sliding surfaces of the chamber ends[3]. The standard vacuum chambers are cleaned using a normal chemical treatment for aluminium alloys. The final cleaning is achieved by a 150°C bake out and Argon glow discharge in the laboratory.

The vacuum chambers of the long straigt sections are made from stainless steel and copper and they are provided with water cooling in order to avoid heating from rf-parasitic mode losses. They are pumped by standard 400 and 100 l/s sputter-ion pumps. The relatively complicated vacuum chambers in the short experimental straight sections are also mainly made of stainless steel using standard fabrications techniques. In the interaction quadrupoles, the pumping speed is improved by integrated sputter-ion pumps working in the magnetic field of the quadrupoles. Integrated sputter-ion pumps working with the detector magnet field have also been installed in some experimental chambers[6]. Some of the vacuum chambers in the short straight sections, such as electrostatic separators etc., have a simple design without water cooling.

The iron yokes of the magnets serve also as radiation shielding for the Compton-scattered synchrotron light. The magnet coils are protected against radiation by 3 mm thick lead shields. The vacuum chambers outside the magnets are also covered by 3 mm lead shields in order to protect sensitive components, such as electronic components, water hoses etc. .

3. VACUUM SYSTEM PERFORMANCE

The two years operational experience with PETRA has shown that beam life times up to 20 h can be achieved without in situ bake out and Argon-glow-discharge cleaning. A base pressure of less than $1*10^{-9}$ mbar without beam can be reached in less than two weeks after venting the vacuum system with Nitrogen for modifications and repairs. This recovery time can be reduced to 10 hours in cases when only small components are replaced.

In the first months of operation, the average pressure increase in PETRA with beam reached a value of about $1*10^{-9}$ mbar/mA and decreased to $1*10^{-10}$ mbar/mA during the experimental runs of PETRA. This behaviour is described by the solid line of Fig.1 as a function of the beam current time integral. It agrees with previous calculations[8] if one assumes that the total inner surface of the vacuum chambers interacts with the synchrotron light. The solid line of Fig.1 is valid for a "virgin" vacuum system which has never been "washed" by synchrotron light. The dashed line gives the behaviour of an already "washed" vacuum section after venting with Nitrogen.

The specific pressure increase remains almost constant in the working beam energy region. Since the pumping speed of the integrated sputter-ion pumps changes with PETRA energy, it means that the synchrotron light induced desorption is proportional to the square root of the beam energy.

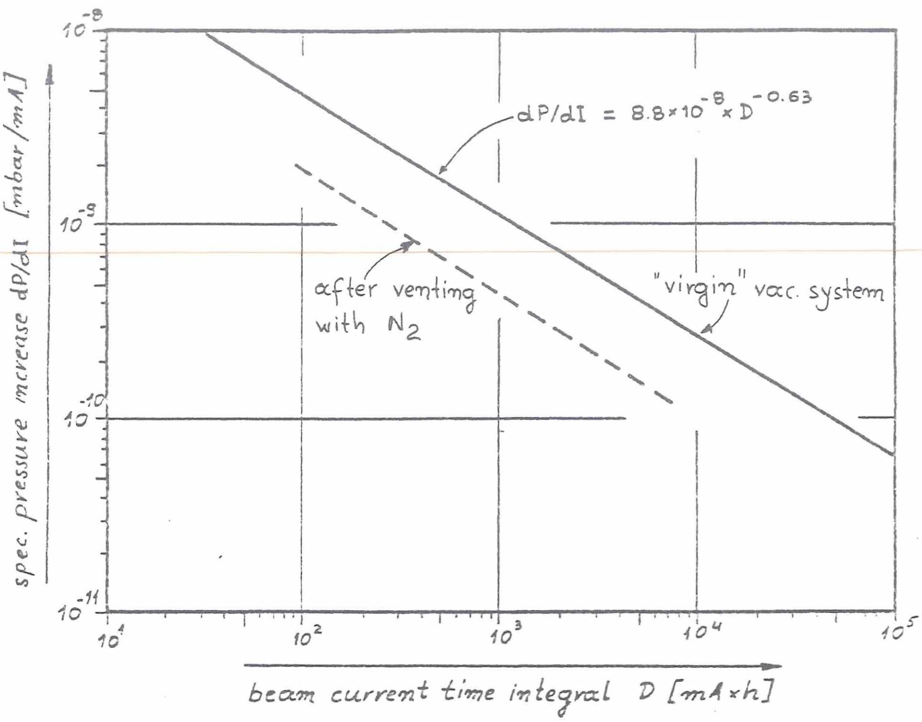

Fig.1 The dependence of the specific pressure increase in PETRA on the beam current time integral

The performance of the installed Viton sealed gate valves is excellent despite previous fears on their use. It seems that the Viton seal degassing rate is smaller than the total degassing rate of the metallic valve parts.

Up to bunch currents of 18 mA, no heating have been observed on uncooled components, such as electrostatic separators. Although large parasitic mode losses have been measured[9], it seems that these modes are not locally absorbed, but rather propagate inside the vacuum system, leading to significantly reduced local thermal loads.

The use of the magnet yokes as shield for the Compton-scattered synchrotron light was also successful. After a PETRA operation of about $5*10^4$ mA*h , the surface of the yokes showed no chemical attack. On the other hand, the operation of PETRA has shown that good radiation shielding of the vacuum chambers is necessary. The observed radiation damages on water hoses which occured during the first months of PETRA operation, when only about 90% of the vacuum system length was shielded, stopped after the lead radiation shielding was completed.

4. CONCLUSIONS

Based on the PETRA experience, the bake out of the vacuum system in the arcs of electron storage rings is not needed. This eliminates the need for larger magnet apertures and the installation of additional bellows for thermal expansion, and also reduces the costs for the power supplies, electrical installation and operation. Glow discharge cleaning in situ is also not necessary, since the vacuum system can be sufficiently cleaned with the synchrotron light.

A shortening of the cleaning time can be achieved by reducing the chamber surface area which interacts with the Compton-scattered synchrotron light. This can be done for instance, by replacing the integrated pumps with small standard pumps[10].

The use of Viton sealed gate valves and simply designed uncooled electrostatic separators can further reduce the vacuum system costs. Finally, the cost saving use of the magnet yokes as radiation shields for the Compton-scattered synchrotron light is recommended. This calls for a strongly coupled design of vacuum system, magnets and shielding for future electron storage rings.

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