STATUS OF THE ESRF VACUUM SYSTEM FROM AN OPERATIONAL POINT OF VIEW

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Abstract

This paper outlines the present status and configuration of the ESRF vacuum system and its performance over the last years. A short overview of the installed vacuum devices is given as well as details of its vacuum system and its weak points. The storage ring (SR) downtimes caused by vacuum accidents have been dramatically improved due to a systematic survey which implements advanced vacuum diagnostic tools. Their use and drawbacks will also be discussed in this paper.

INTRODUCTION

The ESRF is operating since more than 15 years serving 43 beam lines, delivering a stable photon beam with 98% of availability and a mean time between failures of 64 hours. The vacuum system, as one of many subsystems, appears to play a crucial role in the operation of such a facility. The vacuum has a clear impact on the beam quality under certain operation modes as well as downtimes in case the vacuum failures become important. In order to anticipate such failures, we have developed new vacuum survey tools which allow us to detect at an early stage and with a good precision most vacuum problems before they become critical.

DETAILS OF THE VACUUM SYSTEM AND ITS WEAK POINTS

The majority of vacuum interventions take place in the so called Insertion Device (ID) sections, out of which 28 are devoted to the production of brightness synchrotron radiation for the ESRF users and in-house research. The most represented vacuum chamber here is the non-evaporable getter (NEG) coated aluminium vacuum chamber with 10mm external vertical aperture, an elliptical beam chamber of 57 by 8 mm^2 and typically 5m in length but also 11 In-Vacuum undulators of typical 2m magnetic length, among them one prototype of a cryogenic cooled permanent magnet undulator (CPMU) which is discussed elsewhere [1].

In order to push towards new un-bakeable cryogenic cooled permanent magnet structures, we installed an un-baked conventional In-Vacuum undulator with the aim to test their behaviour with stored beam. The vacuum behaviour of this device followed smoothly that of a baked system by a factor 2 (see Fig.:1, total pressure gauges). The partial pressure analysis of its residual gas with 200mA of stored beam showed along the typical gas pattern of Hydrogen, Carbon Monoxide, Carbon Dioxide and Methane, also a high amount of water and rather high mass hydro-carbon components (see Fig.: 2).

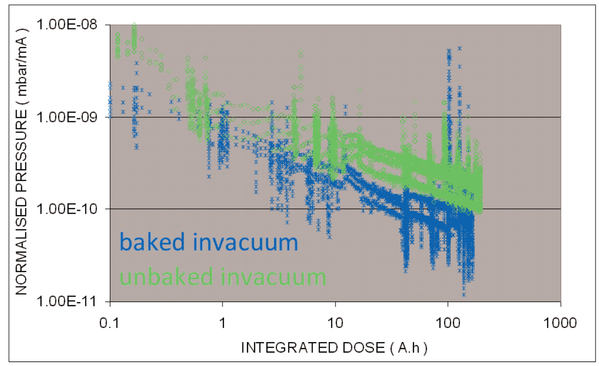

Figure 1: Vacuum conditioning behaviour of baked and un-baked 2-m long In-Vacuum undulators.

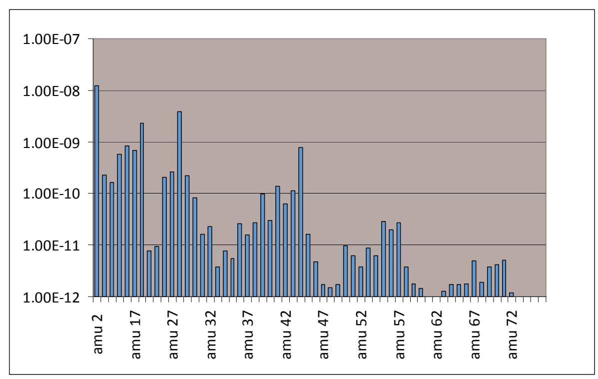

Figure 2: Residual gas analysis of a un-baked In-Vacuum undulator @ 200mA, first stored beam.

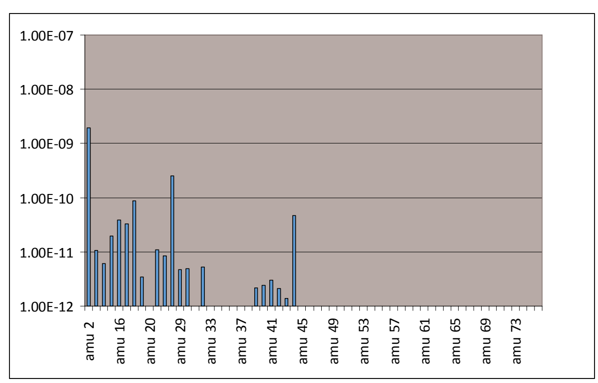

Figure 3: Residual gas analysis of a un-baked In-Vacuum undulator @ 200mA, 720 Ah accumulated beam.

This residual gas pattern conditioned smoothly with the accumulated electron beam (see Fig.: 3)

Problems on the 10mm External Height Insertion Device Vacuum Chambers

On some of the in-house NEG-coated chambers leaks developed from the cooling water circuit to the outside, so water was sprayed in the tunnel. After optical and metallurgical analysis the problem could be traced to impurities of the aluminium extrusion. However a new extrusion has been designed and produced where the cooling circuits are placed in the thicker part of the profile and away from the machined edges where they could be exposed to mechanical stress, for example during the alignment process.

Vacuum Problems with Cavities on the Booster Synchrotron and Electron Storage Ring

Both the storage ring and the booster are equipped with LEP-type cavities. There are two cavities on the booster, and six in three straight sections of the storage ring. Each cavity has two couplers which are fed with RF power as well two to five ceramic ports for RF antennas for field amplitude and phase measurement.

We faced some vacuum leaks on ceramic windows and couplers, especially on the booster. It turned out that each repair or replacement had to be followed by another one only few weeks later. It was concluded that a better vacuum pressure after intervention and gentler RF conditioning of new couplers was necessary to avoid multipacting, which was believed to be the origin of consecutive vacuum leaks on these ceramic parts. To improve the vacuum of the booster cavities, which until summer 2008 had been pumped only by sputter-ion pumps (two 400 l/s triode on each cavity), we added two SAES GP500 NEG cartridges on the back of the sputter-ion pumps for each cavity and baked for the first time the booster cavities at moderate temperature. In addition the RF antenna feedthroughs were Ti coated on the vacuum side to avoid electrical charges on the ceramics.

NEG Coating

One of the two large ESRF coating towers [2] for long vacuum chambers has been modified to cope with six meter long ID vacuum chambers, which will constitute the first step of the ESRF Upgrade program [3]. The first coatings are underway. On the other tool, designed for five meter long chambers some problems appeared when trying to coat long ID chambers with small vertical aperture by means of a two meter long DC magnetron solenoid. As the homogeneity of the plasma all along the lengths could not be assured, a non-uniform layer thickness distribution was obtained. The original configuration consisting of two individual one meter long solenoids was re-established allowing a better local control of the coating parameters. Work has been started to develop a small photo-diode based reflectometer to be passed through the coated chamber to control in-situ the quality of the coating, in a qualitative way.

Crotch Absorbers

In spring 2005 a crotch absorber failed resulting in a water-to-vacuum leak in cell 15 of the storage ring. It was later found by gammagraphy and in-air radiation detectors that inside the cooling tubes, brazed on the back of the GlidCop absorber and hit by the high-energy tail of the dipole radiation (critical energy=20.5 keV, ~2E+10 photons in the range 100-300keV for a 1mrad hor.angle at 200mA nominal [4]), the highly collimated synchrotron radiation could produce local damage (erosion) to the 1mm-thick wall of the tubes (cooling water pressure is kept at around 9 bars), see Fig.4. Therefore, in a first attempt, all the other absorbers of this type (two per vacuum cell, 60 in total) were vertically displaced by 2 mm in order to get the erosion spots out of the beam. This operation was then followed by the production of a third generation of absorbers with a slightly thicker GlidCop layer, in order to absorb the high-energy component of the SR. The crotch absorber exchange program was completed in summer 2008. In parallel, a prototype absorber made up of two horizontal parts avoiding the intersection between cooling water path and dipole X-ray trajectories has been produced and installed in summer 2008 on cell 30 of the machine [3]. Its conditioning has been good, and its new pumping geometry has been validated.

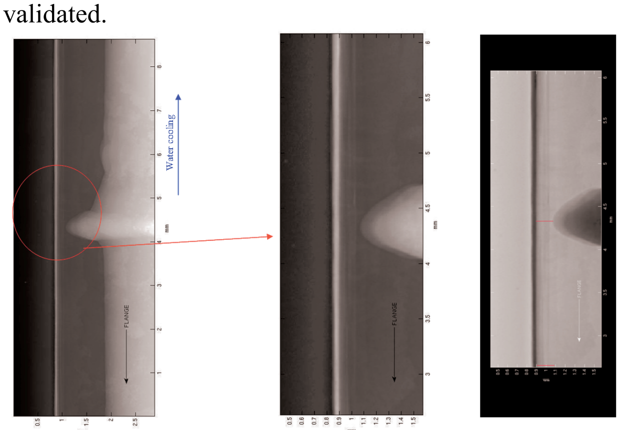

Figure 4: X-ray views of the damage created by high-energy photons on the cooling tubes of the crotch, as taken on ESRF ID6 beamline (courtesy J.C. Biasci, Front End Group ESRF).

SOFTWARE UPGRADE

Our aim was to develop a new vacuum user interface, highlighting any significant changes on any of the SR pressure and temperature sensors, in order to get a global vision of the system. We could identify three different monitor modes which had proven to be useful in the past.

The first mode is a traditional survey of the absolute temperatures or pressures measurements along the SR. Each sensor is represented in a bar chart mode with its actual and saved maximal readout in different colours, since its last manual reset. This enables to identify any unusual pressure or temperature increase since the last check and appears to be a very useful tool for the day to day vacuum follow-up.

Leaks are often identified in a very early state by using a reference pressure survey. During Machine Dedicated Time (MDT) in User Service Mode (USM like), the operator makes a reference survey of all SR Penning gauges and ion pump currents which is normalized to the stored beam current for each specific filling pattern.

The continuous survey of the actual normalized SR pressure readouts normalized with the reference pressure survey of a specific filling mode indicates the smallest unusual pressure variation (see Fig. 5). A derivation by a factor of several units (3-4) already indicates an unusual pressure rise which may hint at an initial phase of a leak or thermal problem.

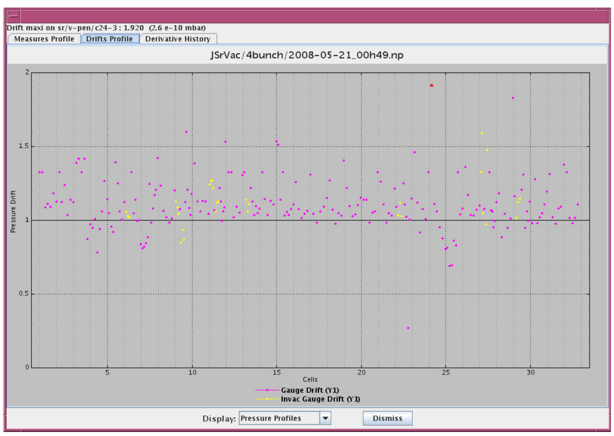

Figure 5: Example of a SR pressure reference survey

The third mode is dedicated to giving a survey of any relative pressure and temperature changes within a short period of time from one to several hours. This derivate signal of gauge and pump pressures, normalises the actual pressure readings to the pressure readings taken sixty seconds earlier.

The thermocouples survey is done in a different way, due to their locations on the external side of the vacuum chambers and therefore slow response times. Instead of looking to the relative temperature changes, we normalize each thermocouple with the average value of all thermocouples belonging to the same family (i.e. installed at equivalent location on chambers of the same type).

These relative changes of all pressure sensors or thermocouples over the SR are displayed in a 3-dimensional survey by using a dedicated colour code, as exemplified in Fig.6.

This application is very helpful to immediately identify and localize any pressure or temperature increase linked to the actual SR operation such as: lifetime accidents, ID gap changes, orbit feed-back and steering magnets problems, emittance instabilities, and other faulty equipment.

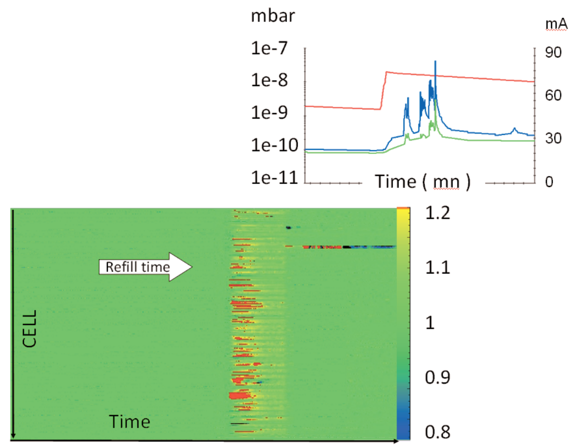

Figure 6 Example of a SR derivative pressure survey

This temperature survey can be displayed by families. This allows a fast detection of unusual heat loads, cooling problems or misalignments or RF-liner problems along the SR chambers.

All these software applications have been carefully documented and transformed into procedures which are readily available to the (at least) two persons who are at any time in the control room of the accelerators, during operation.

CONCLUSIONS

After more than 15 years of continuos operation, in order to maintain the very high reliability and beam availability figures of the past years, and capitalising on the experience gained during this time, we have developed some rather sophisticated procedures and tools which allow us to anticipate vacuum problems and minimise down-times of the accelerator chain. The upgrade program of the ESRF, and the attendant modifications to its vacuum system, will call for a careful utilisation of the diagnostic tools which have been described above. We have ideas on how to modify and improve some of the tools described above, and will start doing this in the near future.

ACKNOWLEDGMENTS

Many thanks to the entire Vacuum group, Computer Services and Operation group.

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