

BEAM CLEANING OF THE VACUUM SYSTEM OF THE TPS STORAGE RING WITHOUT BAKING IN SITU

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Abstract

A maintenance procedure without baking in situ has been successfully developed and applied to maintain and upgrade the TPS storage ring vacuum system to shorten the machine downtime. The data of photon-stimulated desorption (PSD) reveal that no obvious discrepancy between the in-situ baked and the non-in-situ baked vacuum systems. A beam conditioning dose of extent only 11.8 A h is required to recover rapidly the dynamic pressure of an unbaked vacuum system to its pre-intervention value according to the TPS maintenance experience.

INTRODUCTION

A low dynamic pressure is required to ensure a long lifetime and a satisfactory quality of the stored beam. In the vacuum system of the storage ring (SR), two main sources of gas desorbed from the chamber walls are from the thermal outgassing and from the photon-stimulated desorption. Baking is one conventional method for degassing of the chamber materials to yield a small rate of thermal outgassing, but it is incapable of decreasing also the PSD yield. The PSD yield of the vacuum chamber even after vacuum firing at 950°C [1] is almost identical to that without such a treatment, which implies that an omission of baking in situ has no significant influence on the performance of dynamic pressures for the SR vacuum systems. From an energetic point of view, the energies of some highly energetic photons are more than a thousand times those involved in baking [2]. These highly energetic photons striking the chamber walls can desorb tightly bound gas molecules that baking cannot budge. Furthermore, baking in the tunnel of the storage ring requires both much manpower for tedious preparation and additional clearance between the vacuum chambers and the magnets for heaters that decrease the strength of the magnetic field seen by the electron beams. Hence, most modern synchrotron facilities adopt baking ex situ in the laboratory instead of baking in situ in the tunnel for preconditioning of the vacuum vessels at initial operation [3], and use synchrotron radiation only to condition the SR vacuum systems for maintenance and upgrade afterwards [2,4].

MAINTENANCE AND UPGRADE

There were several vacuum interventions over the past two years for maintenance and upgrade of the SR vacuum systems, as described in the following sections. To shorten the TPS machine downtime, we developed a maintenance procedure that allows the vacuum performance to return quickly to its pre-intervention level without baking

in situ. The steps of the maintenance procedure are described as follows.

1. The vacuum system is evacuated down to 1×10^{-6} mbar using turbomolecular pumps (TMP) combined with dry pumps (DP).
2. All non-evaporable getter (NEG) pumps mounted in the SR vacuum system are activated simultaneously.
3. The sputter-ion pumps (SIP) are switched on after the activation of the NEG pumps is complete.
4. The TMPs and DPs are switched off following isolation of the TMPs from the SR vacuum system when the pressure is less than 1×10^{-9} mbar.
5. Conditioning of the SR vacuum system begins with synchrotron radiation.

SR20 & FE40 Accident

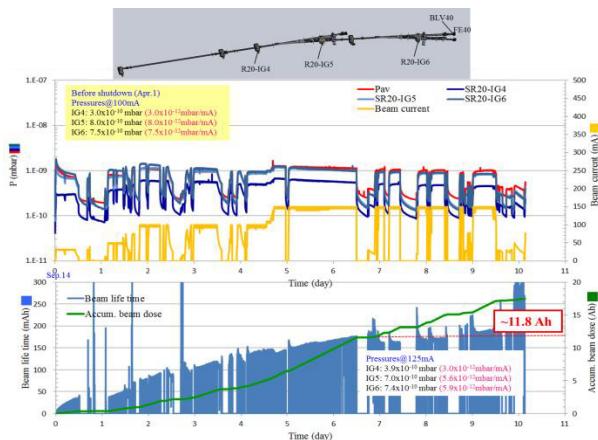


Figure 1: Dynamic pressures and beam life time of SR20.

On 2015 April 29, frontend 40 (FE40) was vented to atmospheric pressure with dry nitrogen for installation of vacuum components. An unexpected venting was also introduced into arc-unit cell 20 (SR20) from FE40 because the frontend valve 40 (FEV40) between them failed to close properly. To recover the vacuum pressure of the SR20, we installed three sets of TMP and DP for roughing; the pressure of SR20 was evacuated from atmospheric pressure to 1×10^{-6} mbar in 6 h. Ten NEG pumps located therein were subsequently activated; the static pressure attained less than 1.2×10^{-9} mbar in 1 day. The dynamic pressures (IG4-6) and beam life time can quickly recovered to their original levels after a beam conditioning dose of extent 11.8 A h, as shown in Figure 1.

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Upgrade of BTS Transport Line

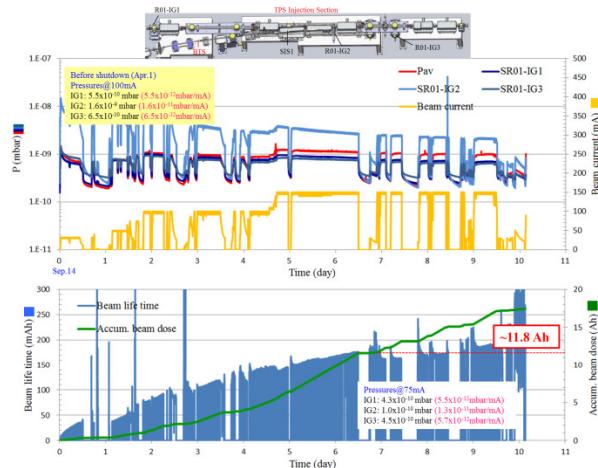


Figure 2: Dynamic pressures and beam life time of SR01.

In 2015 May, an upgrade of the transport line from the booster to the storage ring (BTS) was aimed to decrease the operating voltages of the pulsed septum magnets by altering the bending angles of the booster extraction septum (BES-2) from 4.61° to 4° and of the SR injection septum (SIS-1) from 4° to 3.6° . The BTS transport line and two septa were demounted after dry nitrogen was vented into both the TPS injection section and the BTS transport line until atmospheric pressure was attained. The entire TPS injection section was stored under atmospheric conditions for 1 week, during which the new BTS transport line and two new septa were reconstructed and installed. The maintenance procedure mentioned above was applied to the TPS injection section to decrease the pressure to 1×10^{-6} mbar in 24 h and further to 3.4×10^{-9} mbar in 1 day after activation of the NEG pumps. The dynamic pressures (IG1-3) and beam life time can rapidly return to their original levels after receiving a beam scrubbing of extent 11.8 A h, as shown in Figure 2.

Replacement of a B1 Crotch Absorber in SR02

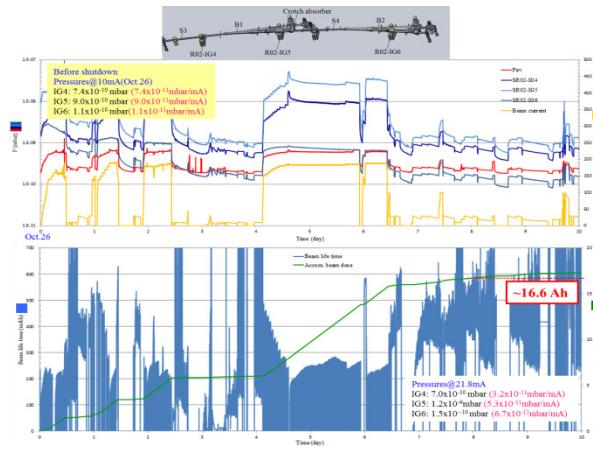


Figure 3: Dynamic pressures and beam life time of SR02 after replacement of a B1 crotch absorber.

In 2015 October, the stored beam current of TPS was gradually promoted to accelerate the beam cleaning so as to meet our commissioning target of stored beam, 500 mA, by the end of 2015, but a pressure burst $> 1 \times 10^{-7}$

mbar near the B1 chamber in SR02 was observed once the current of the stored beam exceeded 200 mA. After several occurrences of leak hunting with a residual-gas analyser (RGA), no leakage was found, but the RGA spectra revealed severe hydrocarbon contamination in this region. Two possible sources of the hydrocarbon contaminants were suspected from the crotch absorber or the B1 chamber. A new crotch absorber was prepared and installed into the B1 chamber to replace the existing one, during which SR02 was exposed to the atmospheric environment for 3 h. Upon application of the above maintenance procedure, SR02 was pumped to a pressure less than 7×10^{-9} mbar in 6 h after activation of the NEG pumps. The dynamic pressures (IG4-6) and beam life time can recover to their pre-intervention values after a beam-conditioning dose of extent 16.6 A, as shown in Figure 3. However, the phenomena of the pressure burst persisted.

Replacement of the B1 Chamber in SR02

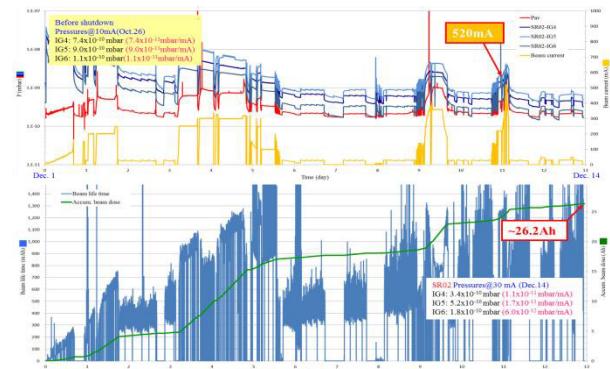


Figure 4: Dynamic pressures and beam life time of SR02 after replacement of a B1 chamber.

The B1 chamber was the other suspect of the indiscernible vacuum problem described above. The TPS unit-arc cell is a 14-m vacuum system that comprises two bending chambers (B1, B2) and two short straight chambers (S3, S4). These chambers were joined together with TIG welding; the entire unit-arc cell had only two vacuum flanges, one at each end; such a design makes difficult a replacement of the B1 chamber [5]. To resolve this issue, a new method of replacement of B1 chamber on site was developed [6]. The new unit-arc cell additionally equips three pairs of flanges, between S3 and B1, B1 and S4, and S4 and B2, according to which the new unit-arc cell is divisible into four subsystems (S3, B1, S4, B2), greatly facilitating the maintenance of this section. A M3 stainless-steel screw covered in melted plastic was found inside the removed B1 chamber, which explains why the RGA signals of hydrocarbon contaminants were so great in the B1 chamber. With the above maintenance procedure, only 9 h was required to evacuate the SR02 down to 1×10^{-6} mbar and a pressure less than 4.5×10^{-9} mbar in 1 day was attained after activation of the NEG pumps. Figure 4 shows that the dynamic pressures and beam life time after the replacement of the B1 chamber in SR02 required a beam-conditioning dose of extent 26.2 A h to recover its pre-intervention level. After this vacuum problem was solved,

the beam current accumulated to 520 mA on December 12, so to exceed our design goal, 500 mA [7].

RESULTS AND DISCUSSION

Table 1 lists the various exposure conditions, histories of vacuum components, durations τ of pumping from atmospheric pressure to 1×10^{-6} mbar, pressures P_{1d} measured after 1 day from the activation of the NEG pumps, and beam-conditioning doses D_η necessary to recover the dynamic pressures to the pre-intervention values for the above maintenance cases. These results are summarized and discussed below.

- i. In case 1, SR20 was vented with dry nitrogen without exposure to the ambient environment; the subsequent pumping duration τ was 6 h and pressure P_{1d} was 1.2×10^{-9} mbar. In case 2, the injection section was vented with dry nitrogen inside and exposed to an atmospheric environment for 1 week, which caused a greater duration, $\tau = 24$ h, of pumping to achieve 1×10^{-6} mbar and a greater pressure, $P_{1d} = 3.4 \times 10^{-9}$ mbar, after activation of the NEG pumps, compared with case 1.
- ii. Although cases 1 and 2 involved different conditions of exposure, the beam-conditioning doses required to recover the dynamic pressures to the pre-intervention values were both 11.8 A h.
- iii. A comparison of cases 1 and 2 reveals that the humidities of the venting gas and the exposure environment were associated with the pumping behavior [8], but less related to the performance of the dynamic pressures, which could be improved only with the synchrotron radiation but had little or no memory effect of the vacuum intervention.
- iv. In case 3, the beam-conditioning dose, 16.6 A h, for the recovery of the dynamic pressures, was greater than that of cases 1 and 2 because the crotch absorber was a brand new vacuum component that had never been conditioned with synchrotron radiation and required a greater beam dose for cleaning.

Table 1: Exposure Conditions, Histories and Parameters of SR Vacuum Systems for TPS Maintenance Cases

Case	Exposure condition		Histories of vacuum components	τ / h	P_{1d} / mbar	$D_\eta / \text{A h}$
	Venting gas	Exposure environment				
1 SR20 & FE40 accident	Dry nitrogen (purity 99.999 %) was vented into SR20 and FE40	Without exposure to the ambient environment	Vacuum chambers (S3, B1, S4, B2) had received a beam dose of 41 A h since installation	6	1.2×10^{-9}	11.8
2 Upgrade of BTS transport line	Dry nitrogen (purity 99.999 %) was vented into BTS transport line and the injection section	Exposure to the ambient environment for 1 week	Vacuum chambers of the injection section had received a beam dose of 41 A h since installation SIS-1 and BES-2 are brand new chambers	24	3.4×10^{-9}	11.8
3 Replacement of a new B1 crotch absorber in SR02	Dry nitrogen (purity 99.999 %) was vented into SR02	Exposure to the ambient environment for 3 hours	B1 crotch absorber was a brand new component Vacuum chambers (S3, B1, S4, B2) had received a beam dose of 125 A h since installation	—	—	16.6
4 Replacement of the B1 chamber in SR02	Dry nitrogen (purity 99.999 %) was vented into SR02	Exposure to the ambient environment for 4 days	Vacuum chambers (S3, B1, S4) are brand new chambers B2 chamber had received a beam dose of 169 A h since installation	9	4.5×10^{-9}	26.2