Technical Note

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Note: **V-1**

STORAGE RING VACUUM SYSTEM PERFORMANCE EVALUATION

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Introduction

The target value of SESAME vacuum system is an average dynamic pressure ~ 1.3 nmbar (~1 ntorr) with 400 mA of circulating current after a dose of 100 Ah, in order to achieve a beam lifetime of 15 ÷ 20 hrs at 2.5 GeV.

In this note, we will reevaluate the vacuum system performance of the bare machine for the updated lattice of SESAME [1], based on the layout shown in Fig.1.
Let us point out that we have adopted the ante-chamber concept in the entire storage ring: this allows, by repositioning the 8 crotch absorbers, to intercept 100% of the emitted synchrotron radiation while reducing the antechamber transverse size to a maximum of ~25 cm.

Figure 1: One Super Period of SESAME storage ring.

The pumping speed arrangement shown in Fig.1 is the most *economical* one that allows achieving the target dynamic pressure value of 1.3 nmbar.

Vacuum chamber

One cell of SESAME vacuum chamber consists of two dipoles, 2 half short straight section, 1 long straight section, and 2 predipole sections: the proper sequence of the various elements is given in [2] while the vacuum chambers are shown in Appendix 1. Full *antechamber concept* is used to improve vacuum quality and radiation interception. A slot height of 12 mm is assumed. Stainless steel 316 LN, with the appropriate thickness, will be used for the vacuum chamber, while OFHC copper will be used for the crotch absorbers.

Crotch absorber

SLS-type Crotch Absorbers are adopted, since the absorbers intercept all the radiation there is no need for distributed ones. Let us remind that for SESAME with the design value of 400 mA at 2.5 GeV, the total synchrotron radiation power coming from the dipoles can be written as:

$$\mathbf{P}\,(\mathrm{W}) = 670.1 \times \Delta\theta$$

where $\Delta\theta$ is the arc of trajectory inside the dipoles, expressed in degrees.

In Tab.1 are reported all the relevant quantities for the 8 Absorbers shown in Fig. 1 (coverage angle $\Delta\theta_i$, total power, linear power density and power density).

Table 1 : SESAME unit cell : relevant absorbers parameters.

Absorber #	Absorber Type	$\Delta\theta_i$ (Degree)	Total Power (KW)	Linear Power Density (W/mm)	Power Density W/mm^2
1	Crotch	(5.5+0.8*)	4.221	24-36.7	8-18.57
2	Crotch	10.5	7.036	21.2-49	6-33.3
3	Crotch	4.5	3.015	18-23	4.51-7.26
4	Crotch	1.45	0.972	6.7-6.95	0.677-0.665
5	Crotch	(5.5+0.55*)	4.054	24-36.7	8-18.57
6	Crotch	10.5	7.036	21.2-49	6-33.3
7	Crotch	4.5	3.015	18-23	4.51-7.26
8	Crotch	1.2	0.804	11.15-11.59	1.7-1.83
Total		**45**	**30.153**		

(*) Coming from the previous dipole.

The values of the maximum linear power density are within the range of SLS-type absorber. The values tabulated in Tab.1 shall be used in the Finite Element Analysis to check maximum Thermal Stresses, Strain, bulk and water temperature, cooling water speed. The Absorber width shall be optimized to withstand high thermal stresses and high temperatures. The Insertion Devices (ID's) contribution is not taken in account: it will be considered at a later stage.
Let us finally point out that due to the physical vertical limitation of the 12mm slot, considering photons with energy higher than 10eV, a total power of 16 W of power is dissipated in the wall of the slot, which corresponds to ~0.05% of the total power per unit cell.

Pressure Profile Evaluation

Method

In order to evaluate the pressure profile along the unit cell we have written a *in house* MATLAB program to solve the linear system of balance equations (the cell is divided in 152 elements, each one ~ 11 cm long with the exception of the element where is located the pump which is 20 cm long):

$$C_i (P_{i-1} - P_i) + C_{i+1} (P_{i+1} - P_i) + Q_i = S_i P_i \quad (i=1, 2,...,152)$$

with the following periodic boundary condition:

$$P_1 = P_n$$

where:

P_i is the unknown pressure of the element i

C_i and C_{i+1} are the gas conductance between element **i** and **i-1** and between element **i** and **i+1** evaluated for CO molecules by using molecular transmission probability tables and monograms [3]

S_i is the pumping speed of element **i**

Q_i is the total gas load of element **i**

The gas load Q_i , neglecting the photoelectron stimulated desorption, is given by the sum of 2 terms, namely:

$$Q_i = Q_{pd} + Q_{th}$$

with:

Q_{pd} stimulated photon desorption for the copper absorber

Q_{th} stainless steel chamber gas load due to thermal desorption

In practical units:

$$\mathbf{Q_{pd}}\ [\text{mbarxliterxsec}^{-1}] = 5.6 \times 10^{-21} \times \eta \times \mathbf{N_\gamma} \times \Delta\theta_i$$

with:

η = 10^{-6} molecules/photon is the yield for OFHC copper after a dose of 100 Ah
$\Delta\theta_i$ is the angle of synchrotron radiation fan intercepted by the absorber
N_γ is the total number of photons/(second x degree) evaluated with the following approximate formula:

$$\mathbf{N_\gamma}\ [\text{Photons / (degree}\times\text{s)}] = 8.08 \times 10^{20} \times \mathbf{E}\ (\text{Gev}) \times \mathbf{I}\ (\text{A})/360 = 2.25 \times 10^{18}$$

for the SESAME design parameters.

The gas load $\mathbf{Q_{th}}$, at 20 °C, is finally obtained by multiplying the surface of each element by a typical coefficient of 10^{-11} [mbar×liter×sec^{-1}×cm^{-2}], achievable with proper cleaning and pre-backing procedures.

Results

Finally, we summarize in Tab. 2 the average and the maximum dynamic pressures as given by our code for 6 different arrangements of the vacuum pumps.

Table 2: Summary of average dynamic pressure for different pumping speed.

Case #	# Pumps in Dipole sections	# Pumps in Straights	Cell Pumping Speed (l/s)	Average pressure (nmbar)	Max pressure (nmbar)
1	4 x150+4x 300	5x500	2550	1.24	1.96
2	2 x 150 +6x300	5x 150	2850	1.15	1.86
3	2x150+4x300+2x500	5x 150	3250	1.12	1.86
4	2x150+2x300+4x500	5x 150	3650	1.08	1.84
5	2x150+2x500+4x300	5x 300	4000	0.92	1.61
6	2x500+6x300	5x 300	4300	0.88	1.50

The corresponding pressure profiles along the unit cell are shown in the Fig. 2 ÷ 7.

Summary

The vacuum system performances based on the full *antechamber concept* have been evaluated for different configurations of vacuum pumping speed. The results will be cross checked with well established codes and they will be the basis for future improvements on both structure and pumping schemes. It is possible to achieve an operational pressure of 1.3 nmbar after a dose of 100 Ah.
For ID's straight section NEG coated vacuum chamber will be used.

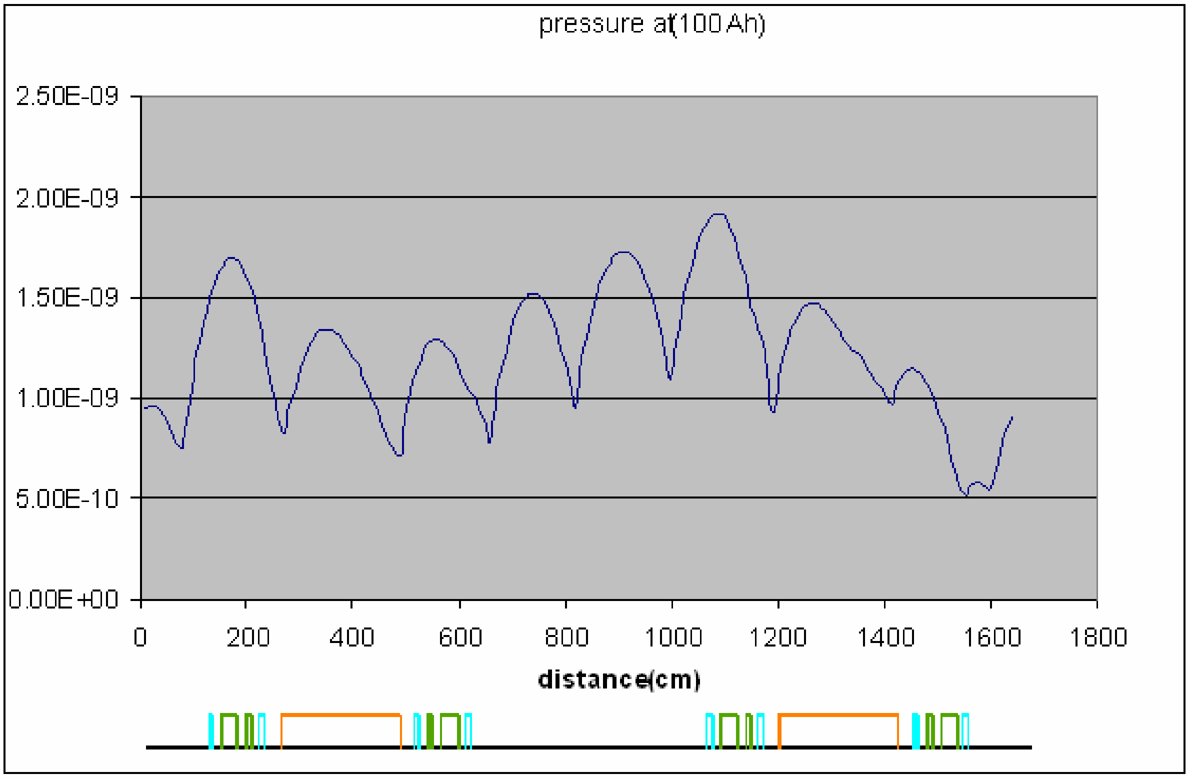

Figure 2: Unit cell dynamic pressure profile (mbar) for case # 1

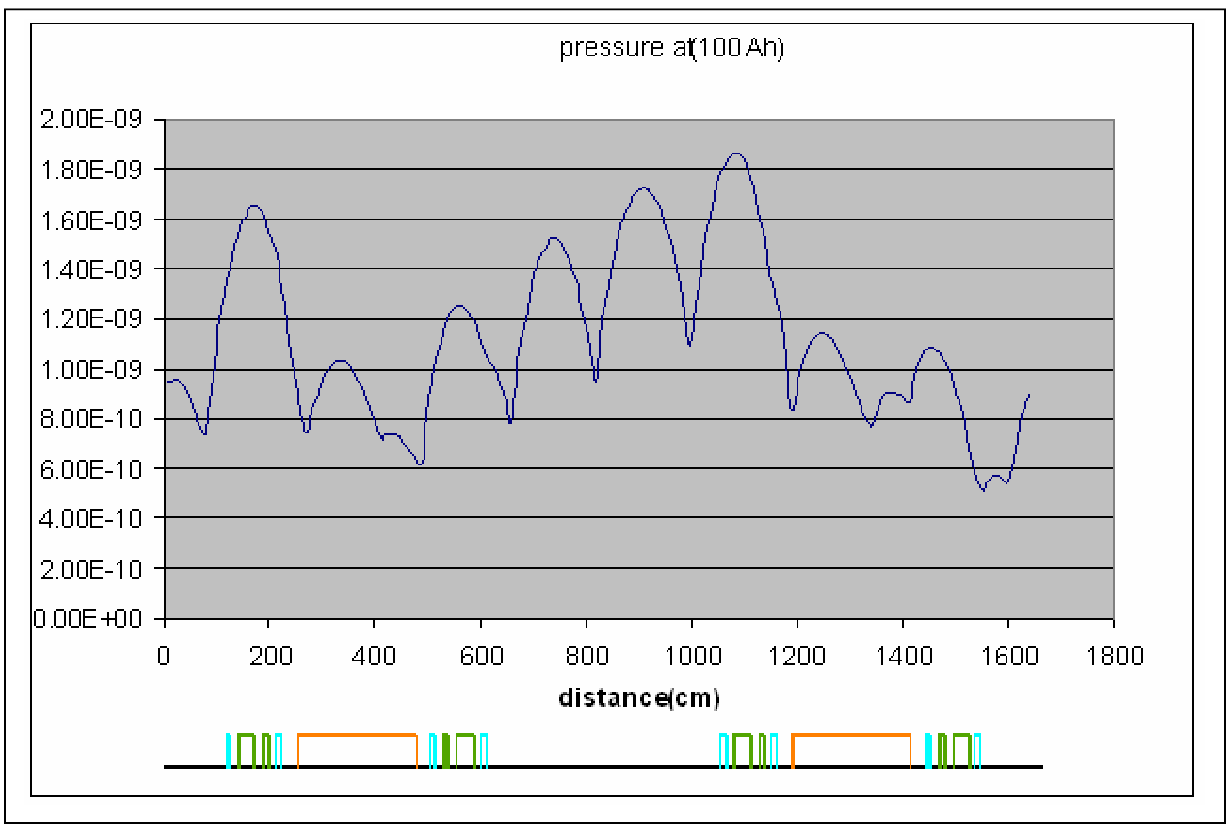

Figure 3: Unit cell dynamic pressure profile (mbar) for case # 2

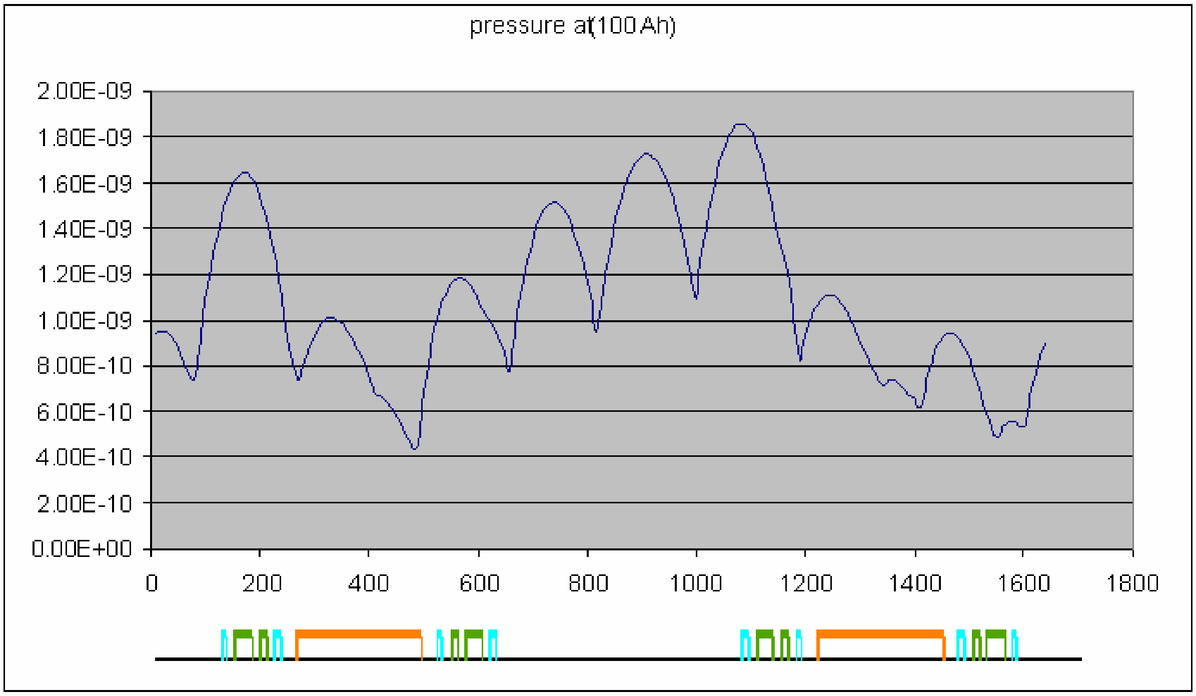

Figure 4: Unit cell dynamic pressure profile (mbar) for case # 3

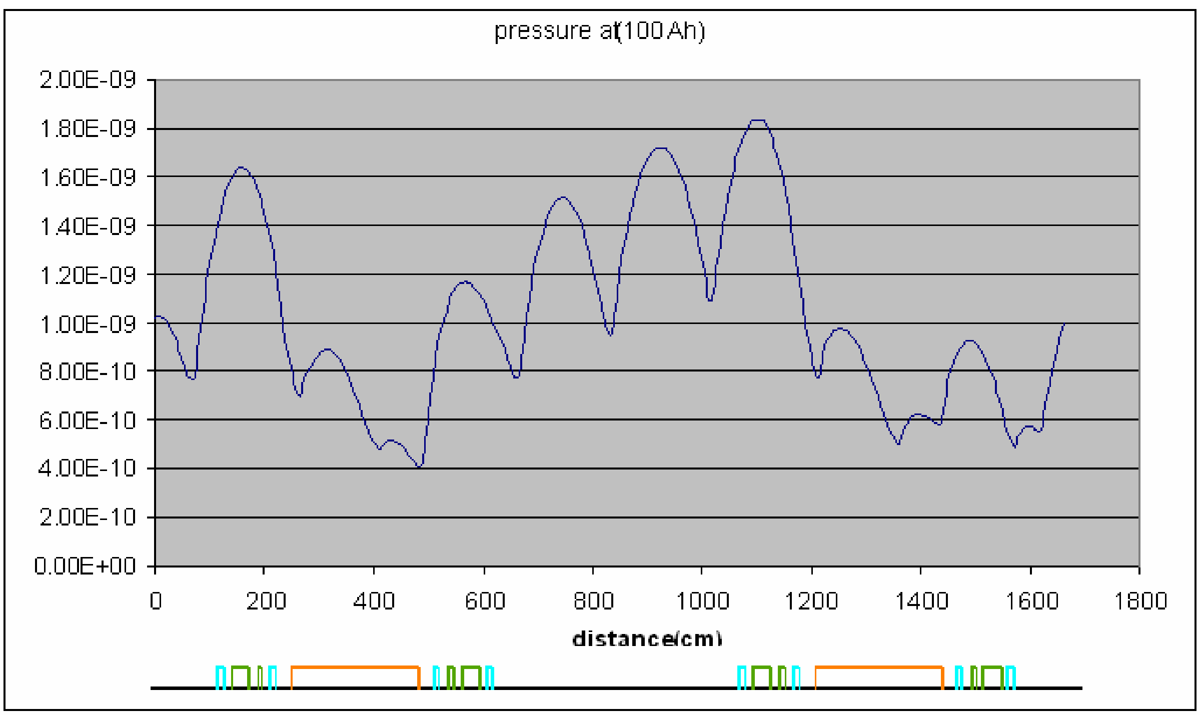

Figure 5: Unit cell dynamic pressure profile (mbar) for case # 4

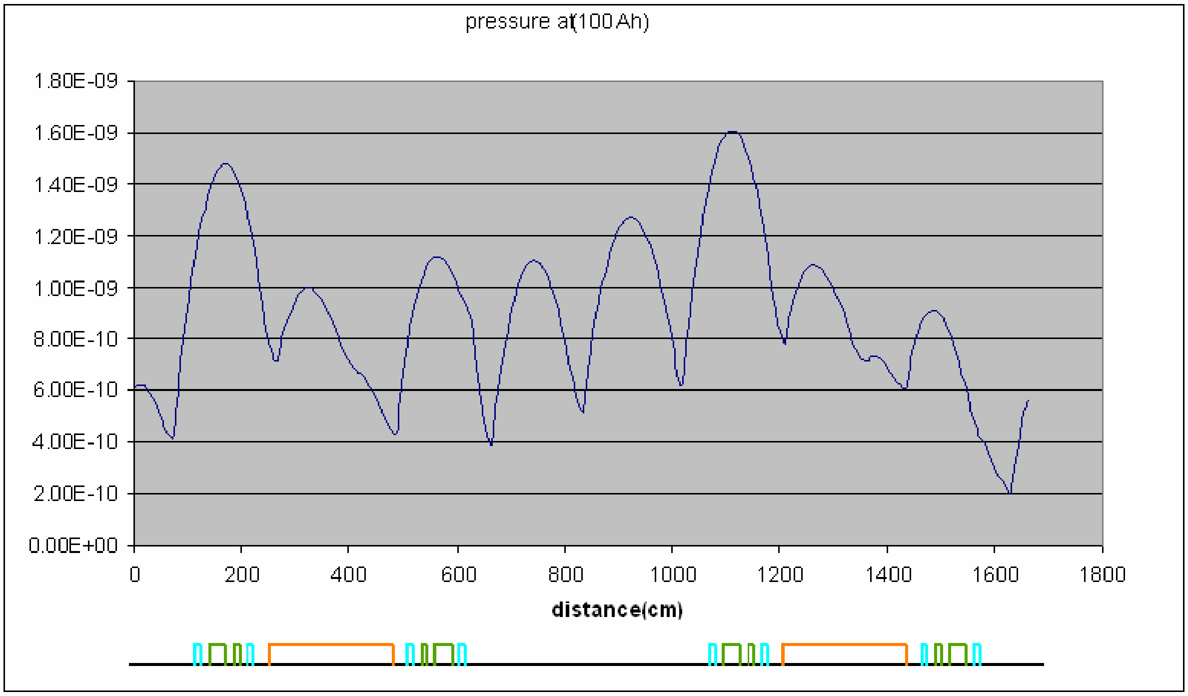

Figure 6: Unit cell dynamic pressure profile (mbar) for case # 5

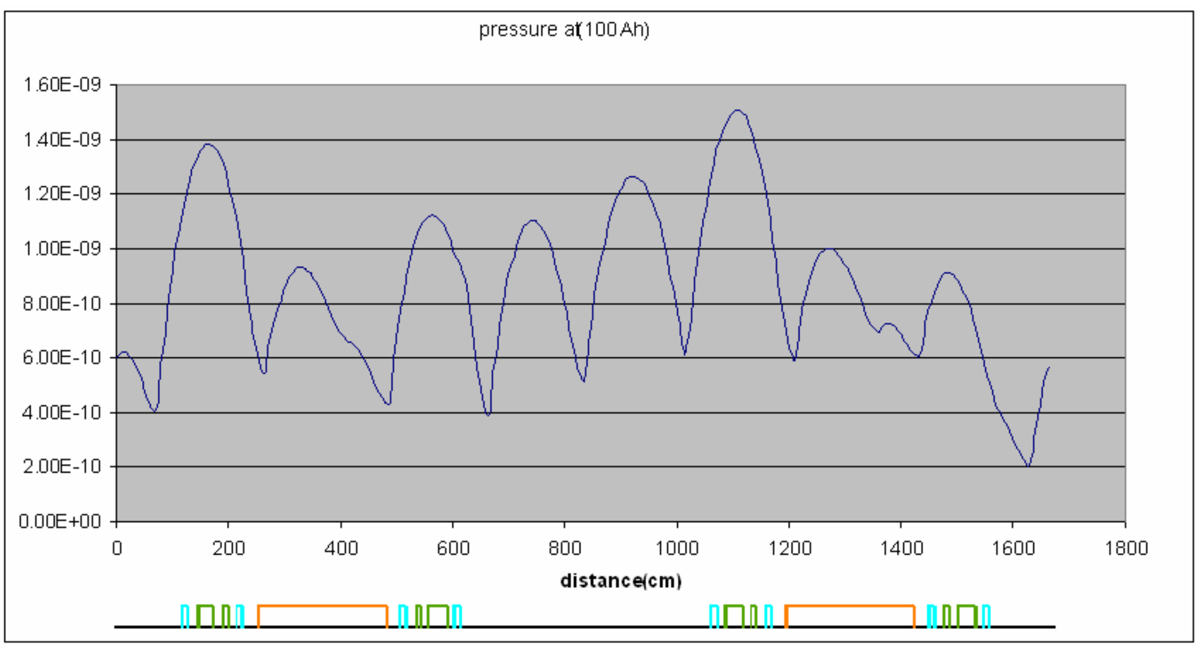

Figure 7: Unit cell dynamic pressure profile (mbar) for case # 6

References
[1] G. Vignola et al. - SESAME in Jordan, PAC 2005 Proceedings
[2] G. Vignola, M. Attal - SESAME Technical Note **O-1**, December 2004
[3] John F.O'Hanlon - A User Guide to Vacuum Technology, 2nd edition,
John Wiley and sons Inc., USA, 1989

Appendix 1 : Vacuum chamber zoom for One SESAME Super Period.