A NOVEL APPROACH IN UHV PUMPING OF ACCELERATORS: THE NEXTORR® PUMP

P. Manini*, A. Conte, L. Viale, A. Bonucci, F. Siviero, L. Caruso,
SAES Getters SpA, Viale Italia 77, 20020 Lainate, Italy

Abstract

In spite of the large dimensions of accelerators, like synchrotrons or colliders, the space available for mounting UHV pumps is getting smaller, due to design constraints, service equipments, conductance, magnets and various instrumentations. This poses challenges to traditional UHV pump designs which are called to deliver more pumping performances in smaller spaces.

A radically new approach is here presented which can mitigate this issue. In this approach Non Evaporable Getter (NEG) and ion pumping technologies are properly combined and integrated in one single pumping device, called NEXTorr®. In this pump, the getter cartridge acts as the main UHV pumping element, leaving to a small sputter ion pump the ancillary task of removing noble gases and methane, not pumped by the NEG. This design allows achieving large pumping speed in a very small package as well as delivering interesting pumping synergies. The main features of this new pump, including pumping tests and example of applications will be reported, with a special focus to accelerators and high energy physics systems. Its impact in the design of vacuum systems for accelerators will also be discussed.

INTRODUCTION

The design and operation of modern accelerators requires the development of vacuum groups able to deliver higher pumping performances with a smaller package. The need for shorter bake-out of vacuum sections like RF cavities, insertion devices etc. is also emerging as a desirable feature for many end users of the accelerator community.

Sputter ion pumps (SIP) are widely used in large vacuum systems due to the ability to adsorb all gases, the absence of lubricants and vibrations. The main disadvantage of this kind of pumps is related to a significant decrease of pumping speed in the UHV-XHV range, in particular for hydrogen. This can be mitigated using larger ion pumps, which implies however a considerable increase of the size and weight of the vacuum system. Due to their high pumping speed in a very compact size, NEG pumps are successfully used in combination with SIP to improve the system base pressure, mainly limited in the UHV-XHV range by H_2.

In this paper we present a new approach to the combination of NEG and SIP pumps, based on the integration of the two technologies in one single unit, called NEXTorr®. We briefly discuss the main features achieved by this pump configuration, such as the pumping synergy between the NEG and the SIP elements, and we show experimental results of pump-down tests comparing the combination pump with a commercial SIP.

*paolo_manini@saes-group.com

ADVANTAGES OF THE NEXTORR CONFIGURATION

The approach followed in the design of the new pump reverses the common way of combining NEG and SIP technologies. Rather than using the NEG pump as an addition to boost the performance of a much larger ion pump, the NEG is here used as the main pump of the system, while a small SIP takes care of gases not pumped by the getter, i.e noble gases and methane. Such approach is supported by studies carried out by Benvenuti et al. [1].

In the NEXTorr® the NEG part is a stack of sintered St172® alloy disks, protruding into the vacuum side of the mounting flange and provided with a tantalum heater for getter activation. On the other side of the flange a small SIP (5 l/s N_2) is connected. The connection flange of the two elements has been designed in order to enhance and exploit synergy effects (described below) and improve the efficiency of the ion pump. The NEG cartridge delivers pumping speed for H_2 of 100 l/s but larger speeds are also possible (new pumps up to 1000 l/s are under development). Given the large capacity for active gases (water, carbon oxides, nitrogen etc.) in a compact size, this combination pump is by far smaller and lighter than a SIP of the same nominal speed, as shown in Fig.1.

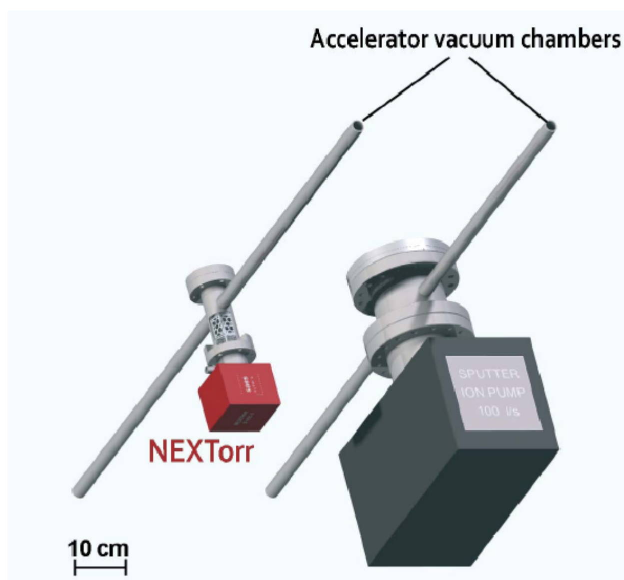

Figure 1: Artistic view of the NEXTorr® D100-5 compared with an equivalent ion pump.

Copyright © 2011 by IPAC'11/EPS-AG — cc Creative Commons Attribution 3.0 (CC BY 3.0)

Performances of the NEXTorr® have been thoroughly characterized for different gases like H_2, N_2, O_2, CO, CO_2, Ar and CH_4. In Fig. 2 we report the sorption curves according to the ASTM F798-97. Other aspects related to the pump operation, including Ar instability, have been also investigated (results will be published elsewhere).

A remarkable benefit offered by a NEG is that no power is needed to operate it, therefore the pump is able to mitigate vacuum degradation for long periods in case of power failure in the system. Moreover, the presence of a small ion pump instead of a larger one results in a lower outgassing rate. Such features are of particular importance for accelerators, where the occurrence of events compromising vacuum integrity has to be properly managed.

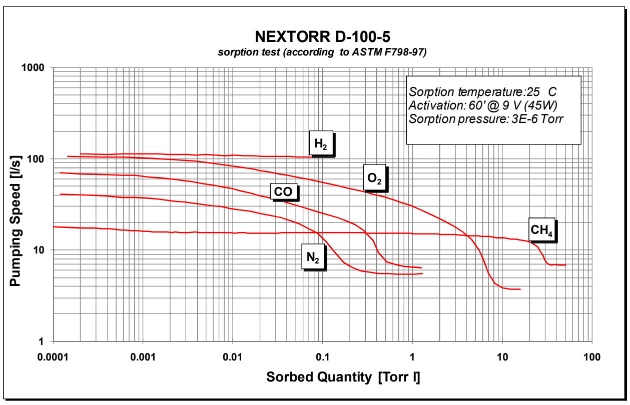

Figure 2: Typical sorption curves of the NEXTorr® D100-5.

Figure 3: Picture of the UHV test bench with the SIP and the NEXTorr® D100-5 installed.

EXPERIMENTAL RESULTS

Pump-Down Tests in a UHV Apparatus

The performances of a NEXTorr® D100-5 have been directly compared with a 120 l/s for H_2 (65 l/s N_2) triode pump mounted on a UHV steel bench (Fig. 3). In a first experiment (Fig. 4) the system has been baked at 170°C for 24 hours, during which the NEG has been kept at about 300°C in order to improve the bake-out efficiency. During the cooling of the chamber the SIPs were degassed and the NEG activated again.

The final vacuum level obtained with the combination pump was lower ($4x10^{-10}$ Torr vs. $1x10^{-9}$ Torr), in spite of the smaller size and smaller nominal speed. The effect of keeping the getter hot during the bake can be used also to shorten the process time, as shown in ref. [2].

A second test was performed baking the apparatus at 250°C for 110°C (Fig. 5) and again a lower pressure was achieved by the NEXTorr®. At the end of the pump down test the SIPs were turned off. While the NEXTorr was able to maintain the pressure in the chamber in the 10^{-9} Torr range for several days, a sudden rise to the 10^{-7} Torr range was observed with the large ion pump.

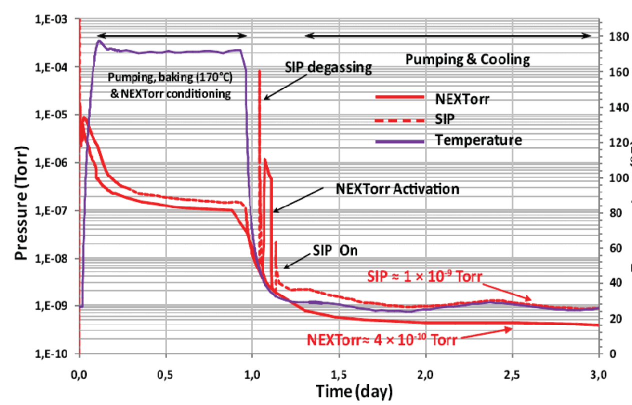

Figure 4: Comparison of the pump-down experiments with combination and conventional SIP pumps (baking 170°C for 24 hours).

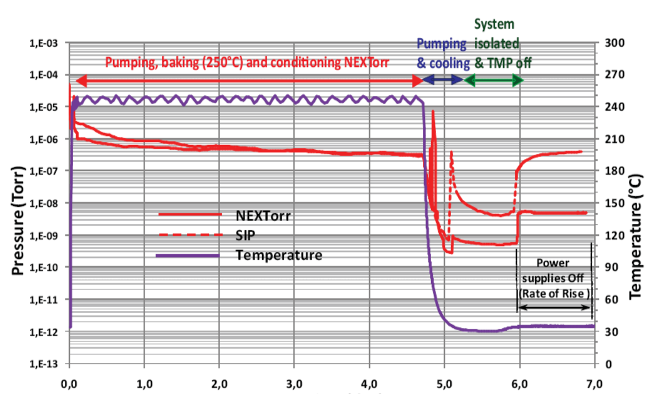

Figure 5: Comparison of the pump-down experiments with combination and conventional SIP (baking 250 °C for 110 hours).

Copyright © 2011 by IPAC'11/EPS-AG — cc Creative Commons Attribution 3.0 (CC BY 3.0)

Pumping Synergy Effect

Figure 2 clearly shows that as long as the NEG element is active the pumping speed of the NEXTorr® is determined by the performances of the getter. Of course, as soon as the NEG element starts to be saturated, the pumping speed drops to the ion pump level. This is true for all the main active gases. It is possible to notice that this same behavior is also observed for methane.

For this gas the above explanation does not hold, for the simple fact that the NEG does not absorb methane at room temperature. Indeed, the higher pumping speed for methane, when the NEG is active, is determined by a synergy effect between the two elements of the NEXTorr®.

In order to confirm this, a quadrupole mass spectrometer (QMS) has been used during an ASTM sorption test to analyse the atmosphere composition. The effect of the QMS on the overall performances of the NEXTorr® was negligible. Fig. 6 shows that during the sorption of methane, in absence of an active NEG, the main gas is not methane as expected, but hydrogen.

The release of hydrogen previously sorbed by the SIP during the sorption of other gases is known as "regurgitation" [3]. In this case, our measurements show that the percentage of produced hydrogen does not change in time, being a kinetic constant of the methane sorption mechanism at a given pressure. Moreover, the pressure of the desorbed hydrogen is stabilized by the SIP itself achieving a quasi-stationary dynamic equilibrium. This phenomenon has been explored and confirmed with other commercial SIP and, although its magnitude seems to depend on the specific system, it is always relevant [4].

Therefore, the actual overall SIP pumping speed is the balance between the methane removal rate and the hydrogen desorption rate. As a consequence of the H_2 desorption, the actual pumping speed is limited to a lower level, i.e. the one shown in Fig. 2 in the final part of the CH_4 sorption curve.

The presence of a NEG, effectively removing the hydrogen desorbed during methane sorption, results in a higher effective pumping speed, as shown in Fig. 2 in the first part of the curve. Fig. 7 shows that during the sorption of methane with active NEG the main gas is methane itself, while hydrogen is limited to a negligible order of magnitude. The design of the pump has been studied to enhance such synergy effect, maximizing the interaction between the gases coming out of the ion pump and the getter cartridge.

CONCLUSIONS

A new combination pump including NEG and SIP elements has been presented. The design of the pump, called NEXTorr® D100-5, is innovative in that the NEG acts as the main pumping element, leaving to a small ion pump the task of removing ungettable gases. Pump down tests under different baking conditions show that the pump provides performance superior to a 65 l/s triode pump with a much smaller weight and footprint. The pump design can be scaled up to deliver pumping speeds for H_2 larger than 1000 l/s. Additional advantages, particularly appealing for application in large vacuum systems, are the ability of maintaining UHV conditions for long time without any power and the possibility of using the getter element of the pump to improve bake-out efficiency. The latter concept can be exploited either to reach a lower base pressure or to shorten the bake duration.

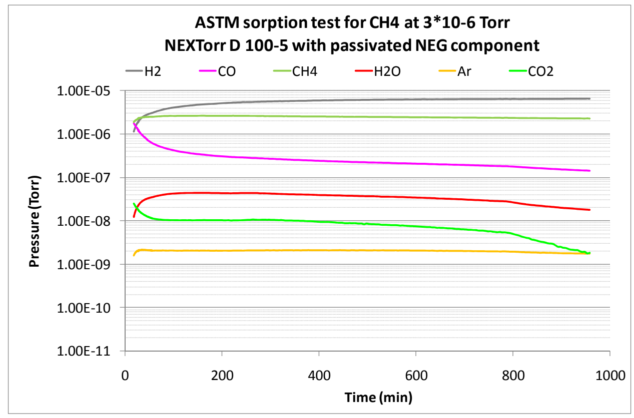

Figure 6: Gas composition during the sorption of methane with passivated NEG element.

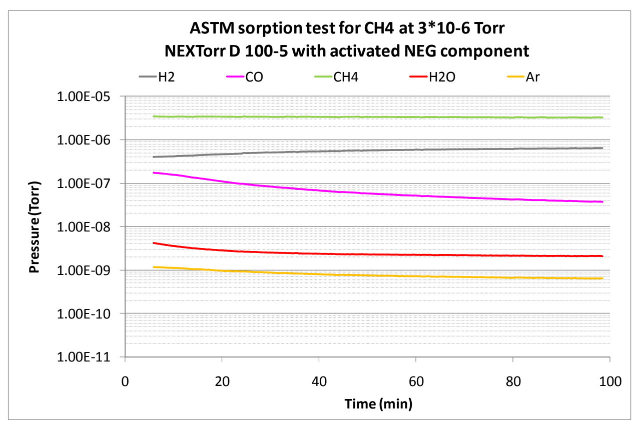

Figure 7: Gas composition during the sorption of methane with active NEG.

REFERENCES

[1] C. Benvenuti and P. Chiggiato, J.Vac. Sci. Technol. A 14(6) (1996), 3278.

[2] C.D. Park, S.M. Chung, P. Manini, J.Vac. Sci. Technol A29(1) (2011) 011012-1.

[3] P.A. Redhead, J.P. Hobson, E.V. Kornelsen, "The Physical Basis of Ultrahigh Vacuum", 1993, Chapman & Hall, p. 409

[4] U.R. Bancea and R.D. Craiga, "Some characteristics of triode ion pumps", Vacuum 16(12) (1966) 647.

Copyright © 2011 by IPAC'11/EPS-AG — cc Creative Commons Attribution 3.0 (CC BY 3.0)