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Evaluation test of NEXTorr® D 100-5 pump

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A new type of UHV pump, the NEXTorr® D 100-5 pump supplied by SAES getters, was tested in the ASTeC Vacuum Science laboratory. The pump provides the pumping speed characteristics which are similar to a 100 l/s sputter ion pump but required much less space, smaller flange and benefits and a smaller weight. Details of the experimental installation, testing procedure and results are described. The main conclusion is that the pump is very promising for use in the UHV vacuum systems of partial accelerator as well as in the laboratory environment. Long term tests of this pump are still on-going.

1. Introduction

The NEXTorr® D 100-5 pump [1], supplied by SAES getters, combines a non-evaporable getter (NEG) element with a small ion pump to provide higher pumping speeds for getterable gases while also having capacity to pump non-getterable gases through the ion pump [2]. It was claimed in the pump brochure that "Thanks to the NEG large pumping capacity for active gases (water, carbon oxides, nitrogen etc.) and the integrated design, the NEXTorr pump is 10 to 50 times smaller and lighter than a SIP featuring similar nominal speed" [3]. The pump can be attached to a system by a DN40 flange connection. The small NEG cartridge extends below this flange while the ion pump is above it.

There are many benefits to having a much smaller and lighter pump for a vacuum system design. The aim of the present work was to test such a pump in the ASTeC Vacuum Science laboratory and to build up a confidence in using this new type of pumps for a future particle accelerator design as well as for various vacuum laboratory facilities. The tests were carried out and the pumping speed and capacity of the NEG for several gases were determined.

2. Experimental Facility

The experimental facility (Fig. 1) used allowed the determination of pumping speeds and sorption capacity by the injection of gases (N_2, H_2, CO, CO_2, CH_4) with known gas flow into the test vacuum chamber [4]. The injection volume of either V = 0.167 *l* or V = 1.67 *l* was initially filled with a selected gas at the pressure ~1 *mbar*. A Baratron® capacity membrane gauge was used to measure the pressure in the volume. The flow rate of gas into the system was controlled using a fine leak valve. The gas flow q is defined by a pressure change $dP_B(t)/dt$ in a fixed injection volume as follows:

$$q\left[\frac{mbar \cdot l}{s}\right] = \frac{dP_B(t)}{dt}V \approx \frac{P_B(t_1) - P_B(t_2)}{t_2 - t_1}V \qquad (1)$$

where t_1 and t_2 are times of corresponding pressure measurements. The amount of injected gas Q from the injection volume is calculated as

$$Q(t)[mbar \cdot l] = \left(P_B(t) - P_B(0)\right)V\,; \qquad (2)$$

where $P_B(0)$ is the initial pressure in the injection volume.

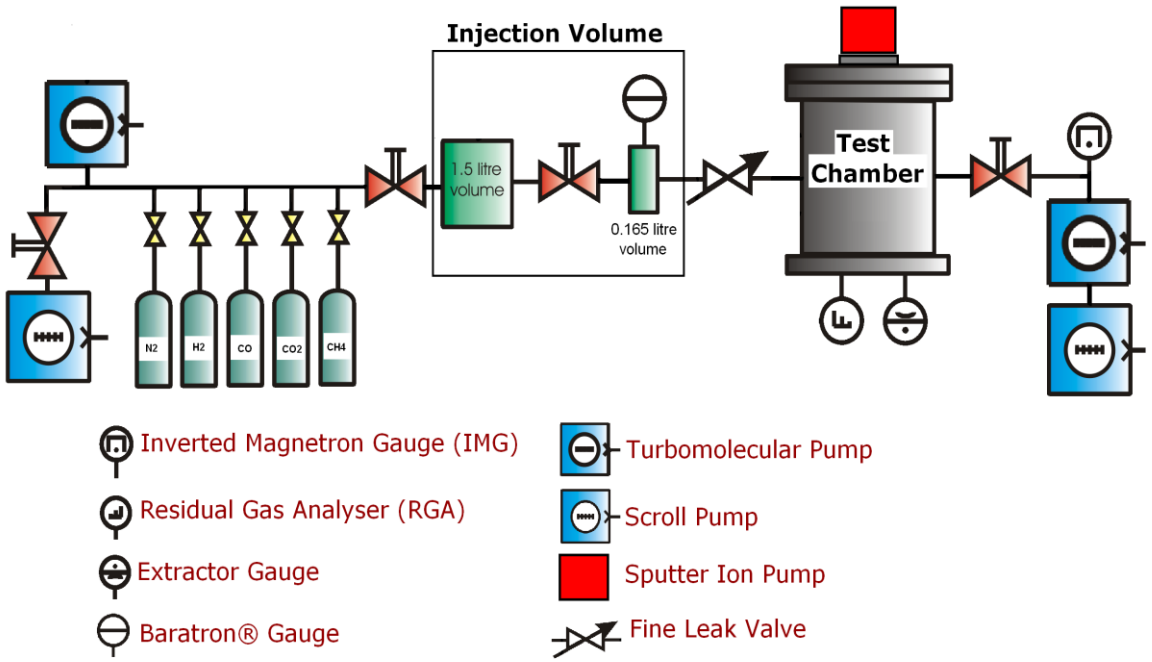

Figure 1. Layout of the pumping speed test facility.

The test chamber was equipped with an extractor gauge and a residual gas analyser (RGA), both attached to the main chamber, to analyse total and partial pressure for all

significant gas species within the vacuum chamber. The RGA was *in-situ* calibrated against the extractor gauge [5]. During bakeout and activation procedures the system was pumped by an external turbo pump which was isolated from the system during tests.

The pumping speed was calculated as

$$S_i(t)\left[\frac{l}{s}\right] = \frac{q}{P_i(t) - P_i(0)} \quad \text{or}$$
$$S_i\left(\frac{t_2 - t_1}{2}\right) \approx \frac{P_B(t_1) - P_B(t_2)}{\left(P_i\left(\frac{t_2 - t_1}{2}\right) - P_i(0)\right)(t_2 - t_1)} V; \tag{3}$$

where $P_i(0)$ is the initial partial pressure of gas i in the test chamber.

3. Experimental Procedure

The pump tests were performed in two geometries (configuration) shown in Figure 2:

- Initially in a closed geometry when the pump was mounted onto a tube offset from the main chamber by 65 mm such that the NEG element did not extend within the main chamber; the bottom of the NEG element was suspended 47 mm above the top of the chamber.
- Then in an open geometry when the pump mounted to a zero length flange at the top of the chamber so that the NEG element was fully contained within the main chamber.

Before gas injections, the system was baked to 200 °C for 24 hours. Note: the NEXTorr pump can be baked up to 150 C without removing the magnets. If the magnets are removed, the pump can be baked up to 250 C. The cables are bakeable up to 200 °C.

N_2, H_2, CO, CO_2, CH_4 were injected in to the system with the flow rate controlled to maintain a pressure of around 1×10^{-6} mbar within the test chamber as measured by the extractor gauge. Gases were injected from the larger (1.67 litres) volume mostly but in some cases the use of the smaller (0.167 litres) volume was required for significant changes in the baratron pressure to be recorded. During the gas injections the baratron pressure, extractor gauge pressure and RGA readings were monitored and recorded. In each configuration, the pumping speed for each gas was found before and after activation of the NEG element. Activations were carried out using the built-in function of the control unit with the chamber pumped by the turbo pump to maintain a low pressure whilst its sputter ion pump is switched

off to avoid contamination and the reduction of its lifetime. Separate power cables for the ion pump and the NEG element connect to the NIOPS-03 power supply. This power supply allows the activation of the NEG element and further re-conditioning when saturation occurs. The built in activation procedure gives a power of 45W for 60 minutes to fully activate the NEG.

The gas injections after activation were carried out until the NEG was saturated where time allowed, with saturation determined as the point where the pumping speed dropped to a similar level to that recorded before activation. After each injection with the NEG activated, the activation process was repeated to have similar conditions of the NEG element.

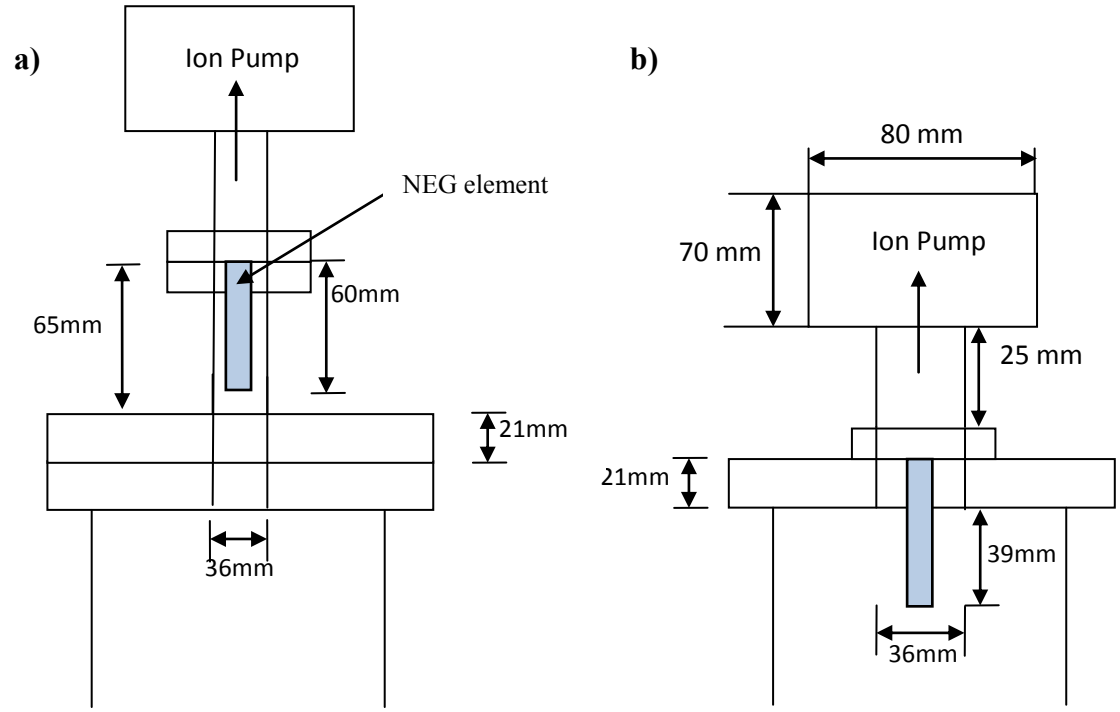

Figure 2a. The pump was attached in the closed geometry with the position of the NEG element shown in blue. **2b.** The pump attached in the open geometry, with the position of the NEG element shown in blue.

4. Results and Discussion

Figure 3 shows the pumping speed measured after the NEG activation in the open geometry as a function of the amount of adsorbed gas. In this case all gases reached saturation except for hydrogen. The pumping speed for hydrogen was found to be 130 l/s initially and showed little decrease with increasing adsorbed gas up to the end point of the injection at 1.6 *mbar·litre* pumped. Carbon monoxide initially pumped at 60 l/s and saturated

at 0.55 mbar·l. Similarly, carbon dioxide was pumped at 55 l/s and saturated at 0.43 mbar·l. Nitrogen pumped at 40 l/s and saturated at 0.25 mbar·l. Methane showed a lower initial pumping speed than other gases, achieving 13 l/s but like hydrogen didn't saturate in the experimental limit of adsorbed gas, although there was a significant decrease in the pumping speed to 8 l/s at 0.06 mbar·l adsorbed. Even if the NEG cartridge alone does not pump methane at room temperature, an improvement of the SIP pumping speed is observed when the NEG cartridge is activated (13 vs. 6 l/s in the open geometry).

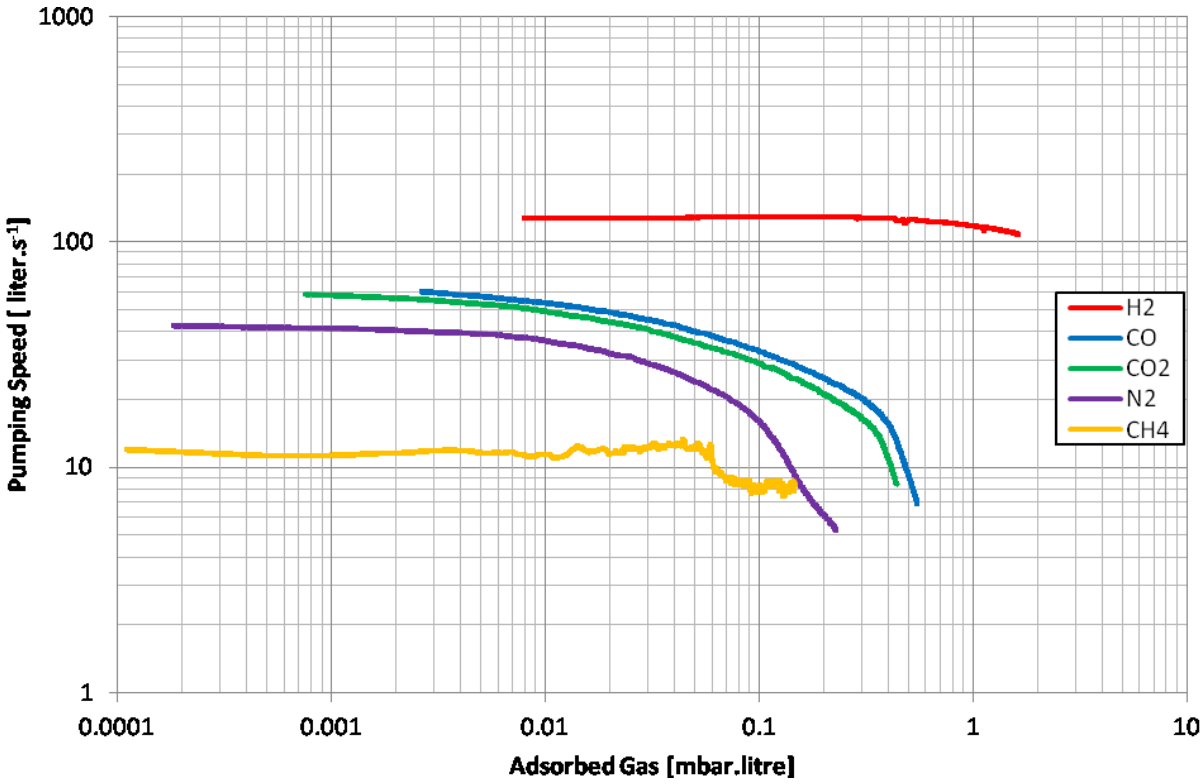

Figure 3. The pumping speed of NEXTorr® D 100-5 pump with activated NEG as a function of adsorbed gas for various injected gases. Results are from the open geometry with the NEG element activated.

The initial pumping speeds before and after activation of the NEG are summarised in Table 1 for both configurations of the pump installation. The values given in the pump manual are also given for reference. Also given are the approximate saturation values of the NEG for each gas where available. One can see that significantly greater pumping speeds were recorded in the open geometry compared to the closed geometry with the 65mm adapter, suggesting that the latter lead to a conductance limited situation rather than being

limited by the pump itself. This conductance limitation is likely caused by the large area occupied by the NEG element covering within the tube, rather than simply being due to the lesser diameter of the tube over a relatively small length.

After activation of the NEG, in the open geometry, pumping speeds for all gases increased greatly except for methane where there was only a small increase. Increases were also observed after activating the NEG in the closed geometry; however the magnitude of these increases was significantly less than in the open geometry.

Table 1. The initial pumping speeds and the saturation points for each gas in each of the experimental geometries. Expected values from the device manual are also shown for reference.

	Closed Geometry			Open Geometry			From the pump manual		
	Pumping speed [l/s]		Sorption capacity [mbar·l]	Pumping speed [l/s]		Sorption capacity [mbar·l]	Pumping speed [l/s]		Sorption capacity [mbar·l]
NEG	saturated	activated		saturated	activated		saturated	activated	
H_2	10	50	>1	10	130	>1.6	—	100	101
CH_4	4	5	—	6	13	>1	5	15	30
CO	10	18	—	7	60	0.55	6	70	0.6
N_2	6	15	0.3	6	40	0.25	5	40	0.23
CO_2	6	15	—	9	55	0.43	—	—	—

Comparing the expected values given in the pump manual with the measured values, CO and N_2 are closely matched. The measured pumping speed for H_2, however, is 30% greater than the expected value. No data was available in the manual for CO_2 for comparison. The measured value of the pumping speed for CH_4 is around 13% less than expected. There is also a decrease in the pumping speed to around 8 l/s at 0.06 mbar·l adsorbed gas. The CH_4 injections were repeated and similar pumping speeds were recorded again with a drop in the

pumping speed at a similar point. However, this drop is not large enough to suggest that the NEG became saturated as the pumping speed is still significantly (60%) greater than that found before activation of the NEG element. The experimental saturation point was taken as the point where the pumping speed was equal to that before activation of the NEG element for an injection of the same gas whereas the data from the manual takes the saturation point at a pumping speed of half the initial value. If this alternative method were used then the results would show reduced capacities compared to those given in the manual.

Also there was some evidence suggesting that the bakeout procedure may have partially activated the NEG. For some injections, before the full activation procedure was run, a small decrease in pumping speed was observed over time. In regular use, this is unlikely to cause problems but in this experiment it may have lead to inflated values for the saturated pumping speeds. This would therefore mean that the values for the sorption capacities were found to be slightly lower than their true values. Anyway, calculations point out that the adsorbed quantity of gas after a 24 hours at 200°C baking process at a pressure of about 10^{-7} mbar is just less than 0.1% of the total capacity available.

After all other tests were completed; O_2 was injected into the system with the ion pump on, while pumping with an external turbomolecular pump. This created plasma to clean the ion pump and the NEG element of any noble gases that would provide a limitation to the pumping speed. After undergoing this process and a reactivation of the NEG element, H_2 and then CH_4 were injected with similar pumping speeds obtained to before suggesting no major benefits to this treatment. However it was interesting to note that following this, the drop in pumping speed for CH_4 observed at 0.06 mbar·l previously was now observed at 0.12 mbar·l. Furthermore, the injection was continued for a considerably longer time than previously and it was observed that the pumping speed recovered over time such that at a value of adsorbed gas of around 0.5 *mbar·litre* there was little difference compared to the initial pumping speed. There was no noticeable saturation for methane up to 1 mbar·l adsorbed.

5. Conclusions and future measurements

The NEXTorr D100-5 provides high pumping speeds and capacity for all gettable gases. Our results are in a good agreement with the data provided by SAES Getters, except for CH_4, which gave slightly lower pumping speed and saturation value than that given in the device manual. It worth mentioning that the H_2 pumping speed was found to be 30% greater than that given by SAES Getters but the H_2 sorption capacity was not measured because the

saturation was not reached in the experiments. The pumping speed for CH_4 is much lower than for gettable gases but it is still sufficient because the outgassing rate of CH_4 is more than two orders of magnitude lower than that for H_2.

The size of the pump is small and convenient to install in various locations, however, one should consider that tubes with an internal diameter ≈ 40 *mm* reduce pumping speed significantly. It would be convenient if the manufacturer considered mounting this pump also on a larger flange such as DN63 and DN100.

Continuing the pump evaluation will involve installing it on a secondary electron yield measurement facility to check how such a pump operates at UHV conditions in long term situations.

Acknowledgments

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[1] Patent n°US8287247 B2: Combined Pumping System Comprising a Getter Pump and an Ion Pump (2012 - Bonucci, Conte, Manini).
NEXTorr is a registered trademark of SAES Group.
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