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Origin of Possible Contamination Introduced by a Turbomolecular Pumping System

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Turbomolecular pumping groups are widely used in accelerators for the pre-evacuation and during the bake-out of the vacuum system. A major requirement for these groups, apart from pumping speed considerations, is the cleanliness of the vacuum produced. In an attempt to clarify this question, a bakeable low-pressure vacuum system has been constructed to allow the direct comparison of the contamination introduced by a turbomolecular pump and by an ideally clean cryopump. This contamination has been checked by the quantitative analysis of the residual gas as well as of the gases desorbed from surfaces under electron bombardment. Contamination by the rotary pump oil is only apparent below 40% of the turbomolecular pump nominal rotation speed. When the pump is stopped, the system is contaminated by heavy hydrocarbons which can be eliminated by a 300°C vacuum bake out.

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ORIGIN OF POSSIBLE CONTAMINATION INTRODUCED BY A TURBOMOLECULAR PUMPING SYSTEM

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Abstract

Turbomolecular pumping groups are widely used in accelerators for the pre-evacuation and during the bake-out of the vacuum system. A major requirement for these groups, apart from pumping speed considerations, is the cleanliness of the vacuum produced. In an attempt to clarify this question, a bakeable low-pressure vacuum system has been constructed to allow the direct comparison of the contamination introduced by a turbomolecular pump and by an ideally clean cryopump. This contamination has been checked by the quantitative analysis of the residual gas as well as of the gases desorbed from surfaces under electron bombardment. Contamination by the rotary pump oil is only apparent below 40% of the turbomolecular pump nominal rotation speed. When the pump is stopped, the system is contaminated by heavy hydrocarbons which can be eliminated by a 300°C vacuum bake out.

1. INTRODUCTION

In accelerators, the residual pressure influences greatly the operational conditions by determining the lifetime of the beams and the parasitic background conditions in the high energy physics experiments[1]. The desorbtion induced by the interaction with the vacuum chamber surface (sometime thousands of square metres) of an intense flux of energetic particles generated by the circulation of the high energy beams mainly determines this residual pressure. Hence, the cleanliness of the vacuum system is of utmost importance to ensure optimum running conditions for accelerators. In these machines, turbomolecular pumps (T.M.P.)[2] are widely used for the preevacuation and during the bakeout of the vacuum system. It is hence of great importance to determine the possible influence of the backstreaming from these pumps on the residual gas composition and on the desorbtion yield of surfaces in systems evacuated by such pumps.

2. THE EXPERIMENTAL SET-UP

The set-up used to measure the backstreaming of the turbomolecular pump is shown on Figure 1: The experimental vessel is connected to two pumping systems (an ideally clean cryopump and a T.M.P.) by a manual valve. It is equipped with modulated Bayard Alpert gauges able to measure pressures in the 10^{-11} Pa range and a residual gas analyzer with a minimum detectable pressure equal to $2x10^{-11}$ Pa. All the vacuum system is constructed out of stainless steel and is bakeable to 300°C. A biased filament is used to bombard the sample using 4 keV electrons.

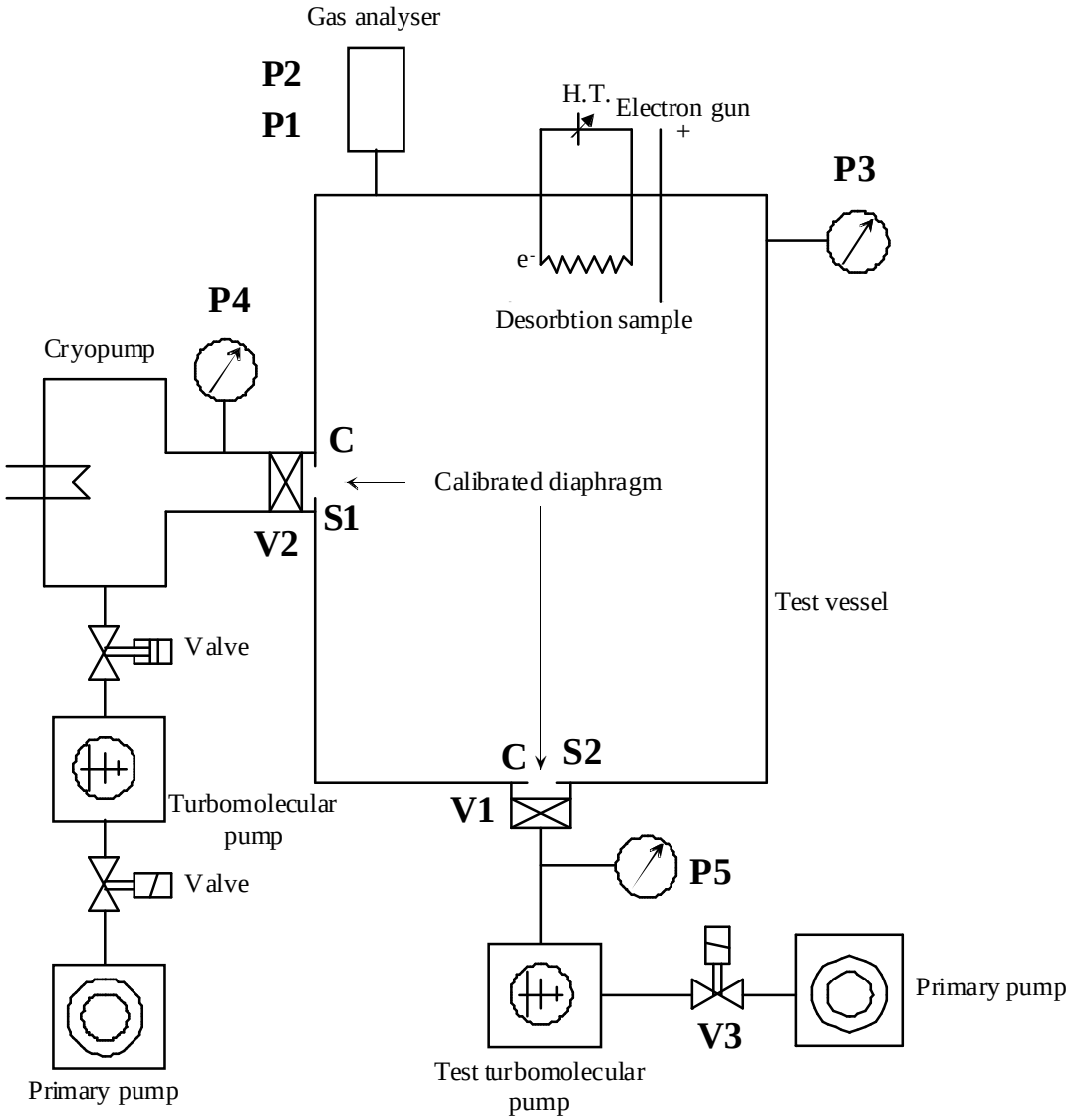

Figure 1 :

The experimental set up

3. COMPARISON OF THE RESIDUAL GAS SPECTRA

A comparison of the residual gas composition in the system measured after a 24 hours 300ºC vacuum bake out is given in table 1 for the three following pumping configuration: cryopumping, 60 l/s conventionnal T.M.P. either at nominal rotation speed (N.S.) or at reduced speed (66% of the nominal speed). The table show that even for a T.M.P. running at reduced rotation speed i.e. with reduced compression ratio, no trace of hydrocarbons with mass higher than 20 is visible (partial pressure lower than 10^{-11} Pa: N.D.). In the following, the backstreaming is hence measured by considering the CH_4 molecule only.
In order to determine more quantitatively the backstreamed flux, one has to take into account the different pumping speeds of the cryopump and of the T.M.P.. Furthermore, in order to enhance the sensitivity of this measurement, the rotation

speed of the T.M.P. was reduced to decrease the compression ratio and to enhance the probability of backstreaming.

Table 1

Residual gas composition for various pumping configuration

Residual gas	Cryopump	T.M.P. 100% N.S.	T.M.P. 66% N.S.
H_2	$3.1x10^{-08}$	$6.4x10^{-08}$	$1.5x10^{-07}$
CH_4	$3.3x10^{-10}$	$4.4x10^{-10}$	$4.8x10^{-10}$
H_2O	$7.6x10^{-10}$	$8.9x10^{-10}$	$1.1x10^{-09}$
CO	$1.3x10^{-09}$	$1.5x10^{-09}$	$1.6x10^{-09}$
CO_2	$3.3x10^{-10}$	$3.6x10^{-10}$	$1.6x10^{-09}$
C_xH_y	N.D.	N.D.	N.D.

The intrinsic hydrocarbon degassing rate of the system is assumed to be measured when it is evacuated by the cryopump. When the T.M.P. is connected to the system, any variation, in excess of that given by the difference of pumping speeds between the T.M.P. and the cryopump can be attributed to the backstreaming of the T.M.P.(Qr).

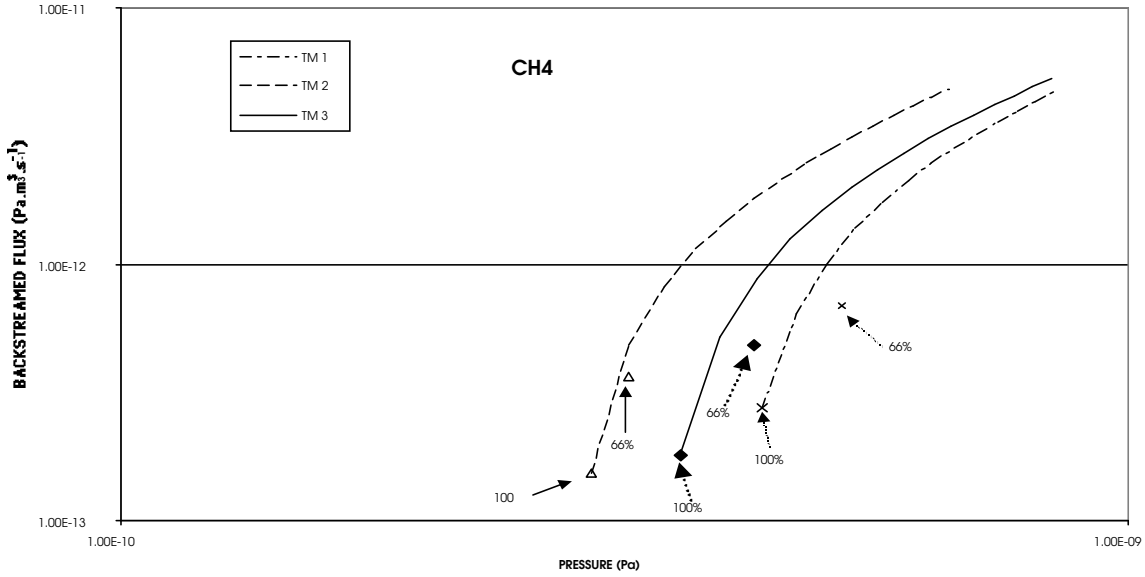

Figure 2: Variation of the methane backstreamed flux with the methane partial pressure in the vessel

The 3 graphs giving the backstreamed flux for 3 types of turbomolecular pumps as a function of the pressure measured in the experimental vessel are given on Figure 2. The dots correspond to the measurements made with these pumps running at 100% and 66% of the nominal speed. In all three cases, at the nominal rotation speed, the backstreamed flux never exceeded 3x 10^{-13} $Pa.m^3.s^{-1}$ measured for methane, the only hydrocarbon peak visible after the bake out of the system. The highest flux was obtained with a 60 l/s T.M.P. operating at 66% speed: $7x10^{-13}$ $Pa.m^3.s^{-1}$.

4. COMPARISON OF THE ELECTRON STIMULATED DESORPTION YIELD

In order to obtain a more accurate measurement of a possible contamination, the electron stimulated desorption[3] of a baked stainless steel sample placed in a system pumped by a T.M.P. was studied. The measurement procedure was the following: After a 300°C vacuum bake-out, the sample was electron bombarded for further cleaning with an electron dose of 9 Cb at 4 keV. The surface was then continuously bombarded with a reduced current ($5x10^{-5}$ A, 4 kV) and the gas composition monitored to determine the desorption yield. The bombardment was then interrupted, leaving the clean stainless steel surface exposed to the residual gas of the system evacuated by a T.M.P.(total pressure $4x10^{-8}$ Pa). After a 24 hours exposure to this residual gas, the electron bombardment was resumed. The same sequence was repeated several times.

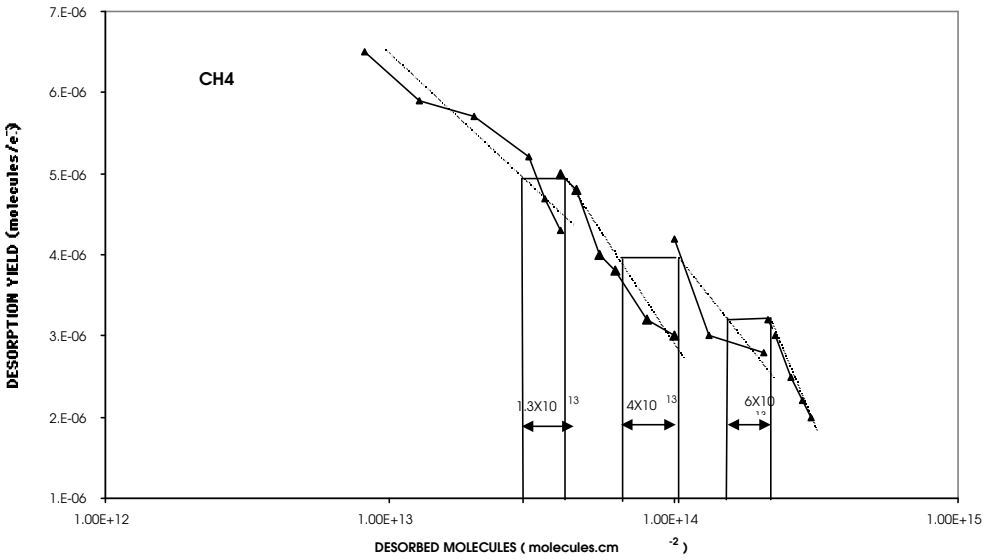

Figure 3: Methane desorbtion yield as a function of the number of desorbed molecules

As in the previous measurements, no traces of hydrocarbons heavier than methane were visible (partial pressures lower than 10^{-11} Pa). The results giving the CH_4 desorption yield as a function of the surface coverage variation are shown on Figure 3. Four lines show the evolution of the desorption yields (the

dots give the measured yields). The discontinuities are due to the increase of the desorption yield caused by the readsorption of the residual gas on the previously cleaned surface. The number of molecules desorbed from the sample surface is obtained by integrating the partial pressure rise during the bombardment. Assuming a monotonous variation of the desorbtion yield with the surface coverage, the number of readsorbed molecules during the period without bombardment can be estimated from the difference of the desorbtion yield measured just before stopping the electron bombardment and immediately after resuming it. The amount of readsorbed CH_4 is given by the rectangles corresponding to the bombardment stoppage. They give an upper estimate of the backstreaming of the T.M.P. For the three experiments considered, the total CH_4 flux including the contribution from the system is 1.8×10^{-8} Pa $m^3.s^{-1}.m^{-2}$. This figure confirms that the order of magnitude obtained in the first experiment is correct and is not significantly higher than the intrinsic contribution of the system to the CH_4 partial pressure.

5. CONTAMINATION INDUCED BY THE STOPPAGE OF A TURBOMOLECULAR PUMPING STATION

An important aspect is the influence on the residual gas during a complete stoppage of the T.M.P., the primary pump being valved off. Two conventional T.M.P. were connected to a baked vacuum system and the residual gas composition was measured while one pump was stopped and isolated from its primary pump. During the slowing down of the T.M.P., gases with mass greater than 20 appeared for a rotation speed lower than 50% of the nominal speed. Figure 4 shows the variation of the gas composition and especially of various masses characteristic of pump oil during the experiment.

Twenty minutes after the stoppage (the total pressure is 3×10^{-4} Pa) heavy molecules (mass 29, 41, 57..) represent with water the most abundant gases showing an important pollution of the system. Heavier masses (e.g. 95) are also visible although in smaller amount (10^{-5} Pa range). The T.M.P. was left stopped for 2 hours during which the pressure remained constant (3×10^{-4} Pa). The T.M.P. was then restarted and the pressure decreased by a factor of 10^3, hydrogen and water being the leading gas. Heavier gases were still present more than 200 hours after the restart of the pump (several percents) but the most visible part of the contamination remains water. After a final bake out at 300°C the traces of are no longer visible partial pressures lower than 10^{-10} Pa.

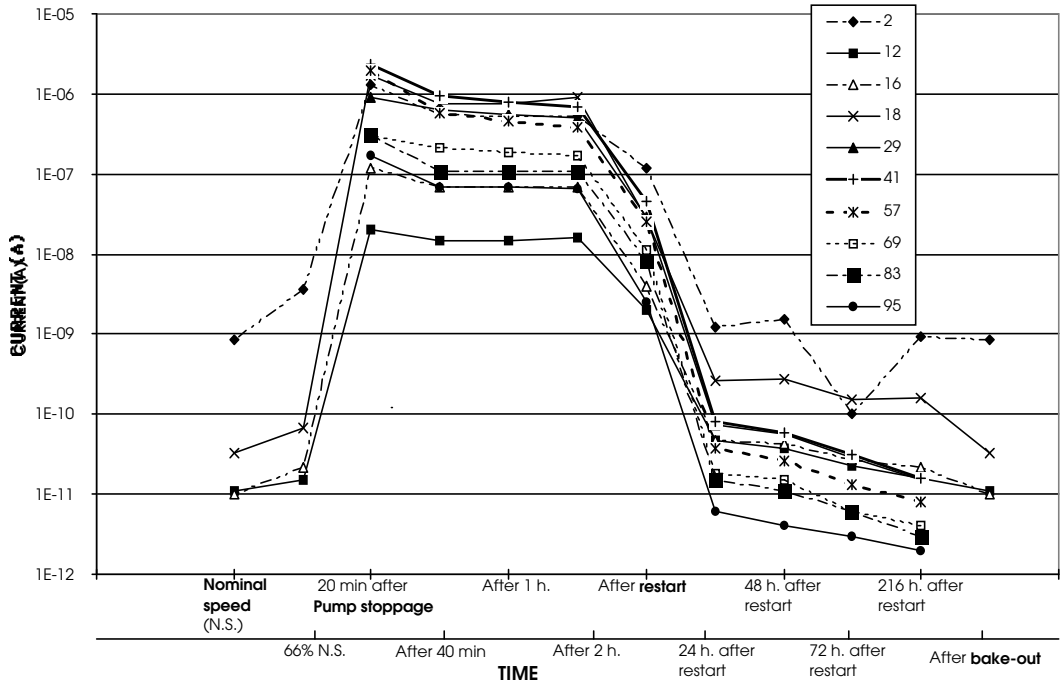

Figure 4: Residual gas composition variation for various status of the T.M.P.

6. CONCLUSIONS

These preliminary results show that the contamination of a clean Ultra High Vacuum system by gases backstreaming from a conventional T.M.P. turning at its nominal speed is very low and thus difficult to detect. The measured flux of methane, the only detectable hydrocarbon under our experimental conditions, has been shown to be lower than $3x10^{-13}$ $Pa.m^3.s^{-1}$. The use of electron induced desorbtion to try to determine the number of hydrocarbon molecules adsorbed by a clean surface has shown to be promising and will be extended to the study of heavier gases backstreamed from the T.M.P. turning at reduced speed. While a T.M.P. is stopped, it is important to isolate it from the evacuated vessel before the rotation speed falls below 50% of the nominal rotation speed to avoid oil contamination. Another important result for the operation of a T.M.P. station is the following: In case of stoppage of a pump, the most persistent contaminant is water and a bake out to 300°C can restore, as far as the static pressure is concerned, the full performance of the vacuum system. Hence one can wonder, with the curently available T.M.P., whether the question of "clean pumping" is not more a problem of "clean procedures" rather than of clean pumps.

Acknowledgements
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