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ULTIMATE PRESSURES OF THE LARGE ELECTRON POSITRON COLLIDER (LEP) VACUUM SYSTEM

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ABSTRACT

When pumping a 12 m long standard LEP dipole chamber with a Non Evaporable Getter (NEG) strip and a 30 ℓs^{-1} sputter-ion pump, an ultimate pressure of about 2 x 10^{-12} Torr is obtained.
The main constituents of the residual pressure are the gases which are not pumped by NEG, i.e., argon and methane.
It is shown in this paper that by adding 6 more 30 ℓs^{-1} sputter-ion pumps, the ultimate pressure decreases to less than 5 x 10^{-13} Torr. In this case hydrogen becomes the leading gas, while both argon and methane should fall below 10^{-13} Torr.

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1. INTRODUCTION

About 80% of the LEP machine consists of 12 m long dipole chambers made from AA 6060 Al alloy extruded tubes [1]. The main pumping speed for these chambers is provided by a linear NEG pump [1, 2, 3] inserted in the chamber as shown in Fig. 1.

All the 2,000 or so dipole chambers produced by industry have been individually tested at CERN prior to installation in the machine. During these test, UHV pumping was provided by the built-in NEG pump and by a sputter-ion pump (SP) of about 30 ℓs^{-1} nominal speed, which had the function of pumping the gases not pumped by the NEG, namely rare gases and methane.

Due to the very large pumping speed of the NEG pump for reactive gases [4, 5] (of the order of 2,000 ℓs^{-1} per metre of pump for H_2, i.e. more than 20,000 ℓs^{-1} per chamber) compared to the speed of the SP, even low Ar and/or CH_4 degassing may limit the ultimate pressure achieved in the chambers. This has in fact been observed during the chambers acceptance tests, mainly due to argon trapped in the welds, which resulted in an average limitation in the low 10^{-11} Torr range, and even much higher in few cases.

Fortunately, argon degassing from virtual leaks decreases with time not only when pumping is applied but also when the chambers are stored under nitrogen. In the latter case, nitrogen replaces argon in the weld porosities and its subsequent degassing is efficiently removed by the NEG pump.

Whenever the argon pressure was negligible, either because of reduced porosities or due to a long storage time, ultimate pressures in the low 10^{-12} Torr were recorded after baking (24 hours at 150°C). The main constituent of the ultimate pressure was methane, while the H_2

contribution was in the low 10^{-13} Torr range. This observation indicates that, by increasing the applied SP speed, pressures consistently below 10^{-12} Torr could be obtained in the LEP dipole chambers.

In order to substantiate this possibility, two dipole chambers have been modified by adding lateral ports such as to allow the installation of six additional SPs identical to the one already used and adequate instrumentation to obtain correct indications in the 10^{-13} Torr range.

The experimental set-up and the results obtained are described below.

2. EXPERIMENTAL SET-UP AND PROCEDURES

The two experimental chambers were equipped with six additional outlets for connecting the SPs and some more outlets for pressure measuring instrumentation.

Both SPs and pressure gauges were linked to the chamber via stainless steel elbows (of 70 ℓs^{-1} conductance for N_2) such as to allow 350°C baking of the gauges and pumps without overheating the aluminium flange of the chamber [1]. Chamber 1 was equipped with 2 Bayard-Alpert (B.A.) gauges of CERN design, suitable for pressure measurements down to 10^{-12} Torr [6, 7] and a modified Helmer gauge which had already been used in the 10^{-14} Torr pressure range [8]. On chamber 2, three B.A. gauges and a Residual Gas Analyser (RGA) were installed.

Initial pump-down and pumping during bakeout were achieved by means of a LEP Turbomolecular pumping station [1]. The nominal pumping speed of the Turbomolecular Pump (TMP) was 170 ℓs^{-1}.

The chamber bakeout was carried out by hot water circulation [1]. After about 20 hours at 150°C, the NEG pump was activated at 740°C by circulating a current of 90 A in the NEG strip [2, 3], the TMP pump was valved off, the SPs were ignited and the pressure gauges degassed. At the end of these operations, i.e. about 24 hours after the beginning of the bakeout, heating was stopped and the chamber cooled by water circulation.

During this sequence, all the SPs were ignited to insure their effective degassing. After reaching a stable pressure (see par. 3) all the SP's but one were switched off such as to reach, for comparison, the standard situation with one SP only, and then switched on one by one. Therefore, pressures on both chambers were measured in seven different conditions of SP pumping speed.

3. RESULTS AND DISCUSSION

The evolution of the total pressure measured by the Helmer gauge and by the two B.A. gauges of chamber 1, and also for comparison by a B.A. gauge on chamber 2 as a function of time is displayed in Fig. 2.

A few hours only after the end of bakeout, in the two chambers the total pressures were close to 10^{-12} Torr, and they reached equilibrium (4 to 5 x 10^{-13} Torr N_2 equivalent) after about two weeks. Partial pressure measurements on chamber 2, shown in Fig. 3, indicate that the ultimate residual (true) pressures were about 1.3 x 10^{-13} Torr for CH_4 and 5 x 10^{-14} Torr for Ar. The H_2 partial pressure cannot be directly measured, because the RGA is affected by a parasitic mass 2 peak. However, by subtracting the Ar and CH_4 partial pressures from total pressure, a resulting (true) H_2 pressure of about 2 x 10^{-13} Torr is obtained.

It is interesting to note that such a H_2 pressure, combined with a NEG pumping speed of 2,000 $\ell s^{-1} m^{-1}$, results in a H_2 degassing rate of 5 x 10^{-14} Torr ℓs^{-1} cm^{-2}. This value is about half that directly measured on other chambers, which had been baked only once, while chamber 2 had been baked 6 times.

The Helmer gauge was equipped with a thoria coated filament, which results in a low degassing of about 5 x 10^{-11} Torr ℓs^{-1}, about one order of magnitude lower than that of the B.A. gauges [7], equipped with a bare tungsten filament. These rates of degassing, combined with the conductance limitation of the stainless steel elbows (see par. 2), should not permit the B.A. gauges to measure pressures in the 10^{-13} Torr range. In this respect the reported results are surprising and indicate that gauge degassing decreases considerably over periods of a few weeks following the decrease of the operating pressure.

The evolution of the Ar and CH_4 pressures in chamber 2 with increasing number of SP's is shown in Fig. 3. While the$\pi\pi$ Ar pressure followed in general the expected behaviour, the CH_4 pressure decreased only marginally when the third SP was switched on, and it even increased when switching on the fourth SP. A total pressure increase when switching on an SP was also observed in chamber 1, where however no RGA was installed (see Fig. 4). Two out of the 14 identical SPs used in this experiment produced a pressure increase at 10^{-13} Torr when ignited. If these two pumps were not switched on, the ultimate pressure in the two chambers was about 4 x 10^{-13} Torr.

4. CONCLUSIONS

The results reported here indicate, as anticipated [9], that pressures in the low 10^{-13} Torr may be obtained on an industrial scale by means of a NEG pump activated by resistive heating.

This implies, however, that a sufficient pumping speed for gases that the NEG does not pump, namely Ar and CH_4 is added. Since the degassing rate for these gases, in good conditions, (both for stainless steel and Al alloys) is of the order of 10^{-16} Torr ℓs^{-1} cm^{-2}, the low 10^{-13} Torr range may be reached if the applied SP pumping speed is of the order of 10 ℓs^{-1} per m^{-2} of vacuum system surface. This conclusion, however, may be falsified by a anomalous CH_4 degassing of SPs at low pressure, a situation which has been observed for 2 of the 14 SPs used in this experiment.

The reported results indicate that pressures in the low 10^{-13} Torr range may be measured quite accurately by means of B.A. gauges of proper design.

References

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Figure Captions

Fig. 1 Cross section of the LEP dipole chamber.
1. extruded Al profile ;
2. cooling channels ;
3. lead shielding for synchrotron radiation ;
4. ceramic insulators ;
5. pumping slots.

Fig. 2 Evolution of total pressures as a function of time in chambers 1 and 2 after bakeout with 7 SPs on.

Fig. 3 Variation of the argon and methane partial pressures, as a function of the number of SPs ignited on chamber 2, about 400 hours after bakeout The Ar and CH_4 measured partial pressures are indicated by dots and triangles, respectively. The dotted lines represent the partial pressures calculated under the assumption that all pumps provide, for the same gas, the same pressure independent pumping speed.

Fig. 4 Variation of the total pressure measured by the Helmer gauge on chamber 1, as a function of the number of SP's ignited, about 400 hours after bakeout.

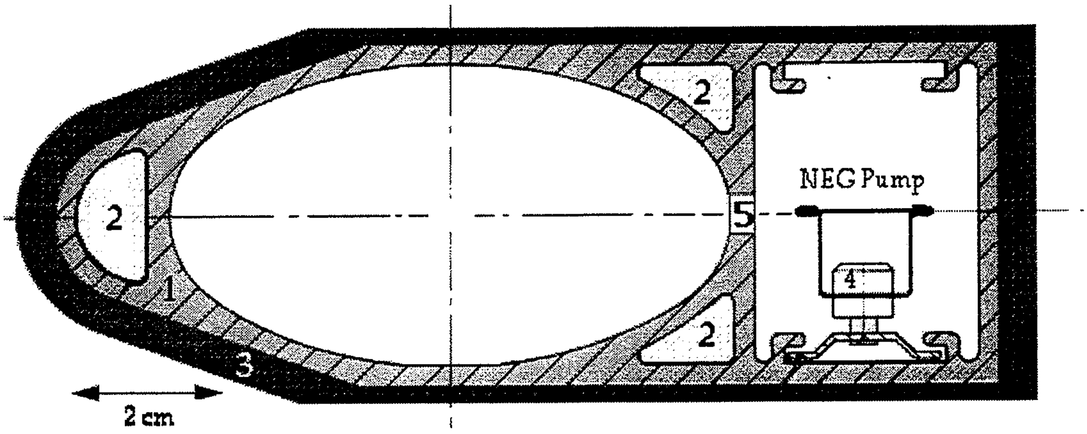

Fig. 1

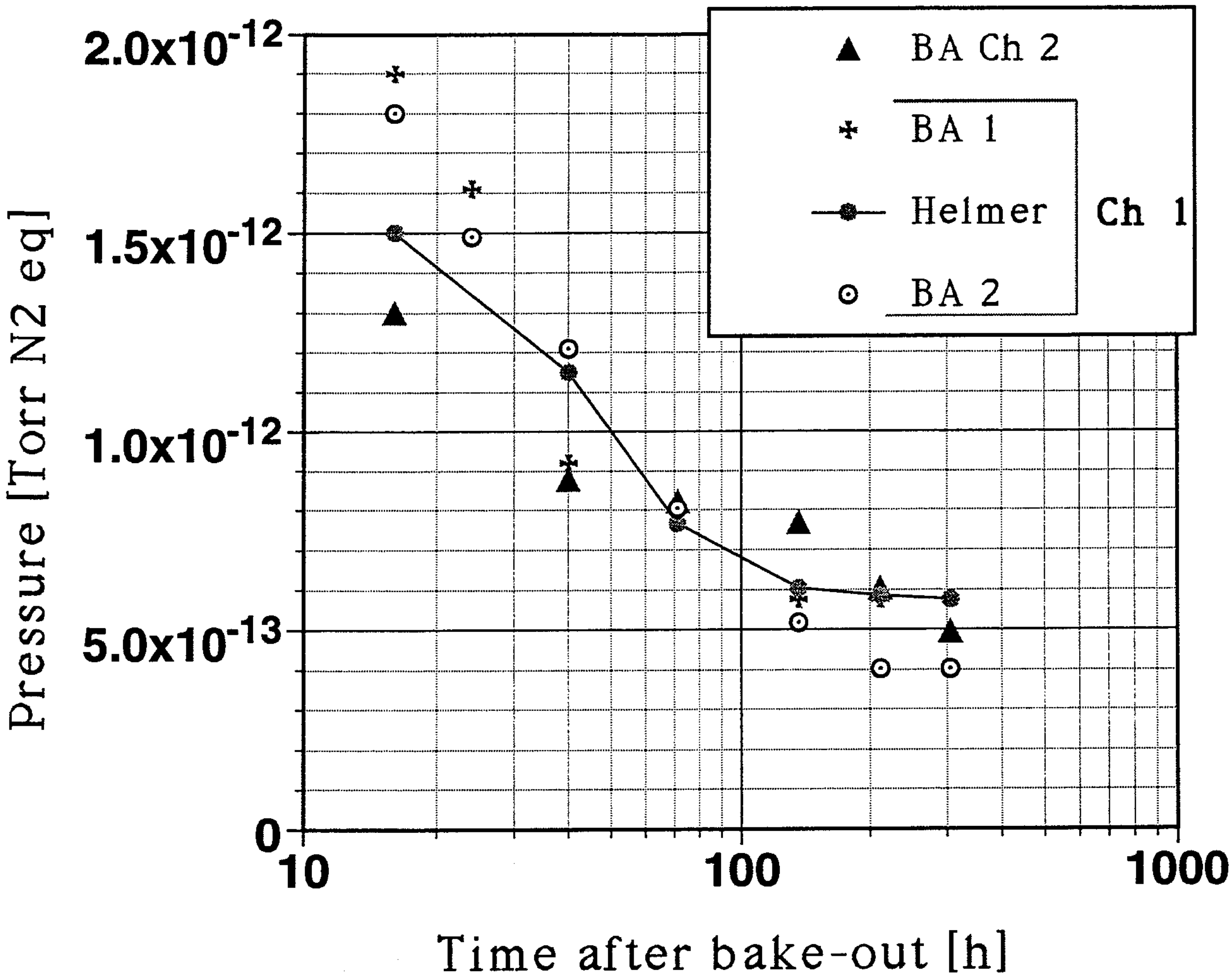
BA Ch 2
BA 1
Helmer
Ch 1
BA 2
2.0x10-12
1.5x10-12
1.0x10-12
5.0x10-13
0
Pressure [Torr N2 eq]
10
100
1000
Time after bake-out [h]

Fig. 2

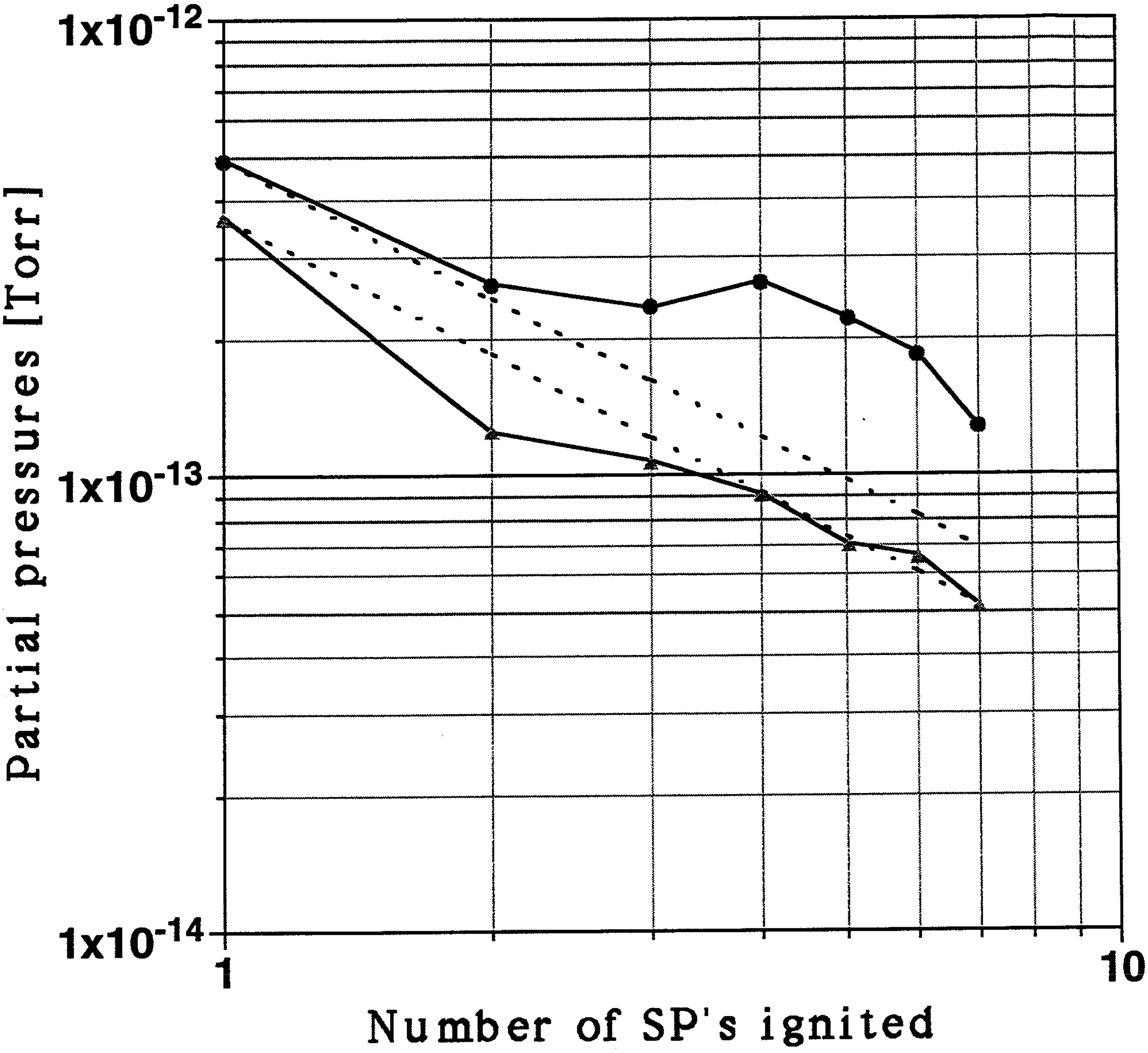
1x10-12
1x10-13
1x10-14
Partial pressures [Torr]
1
10
Number of SP's ignited

Fig. 3

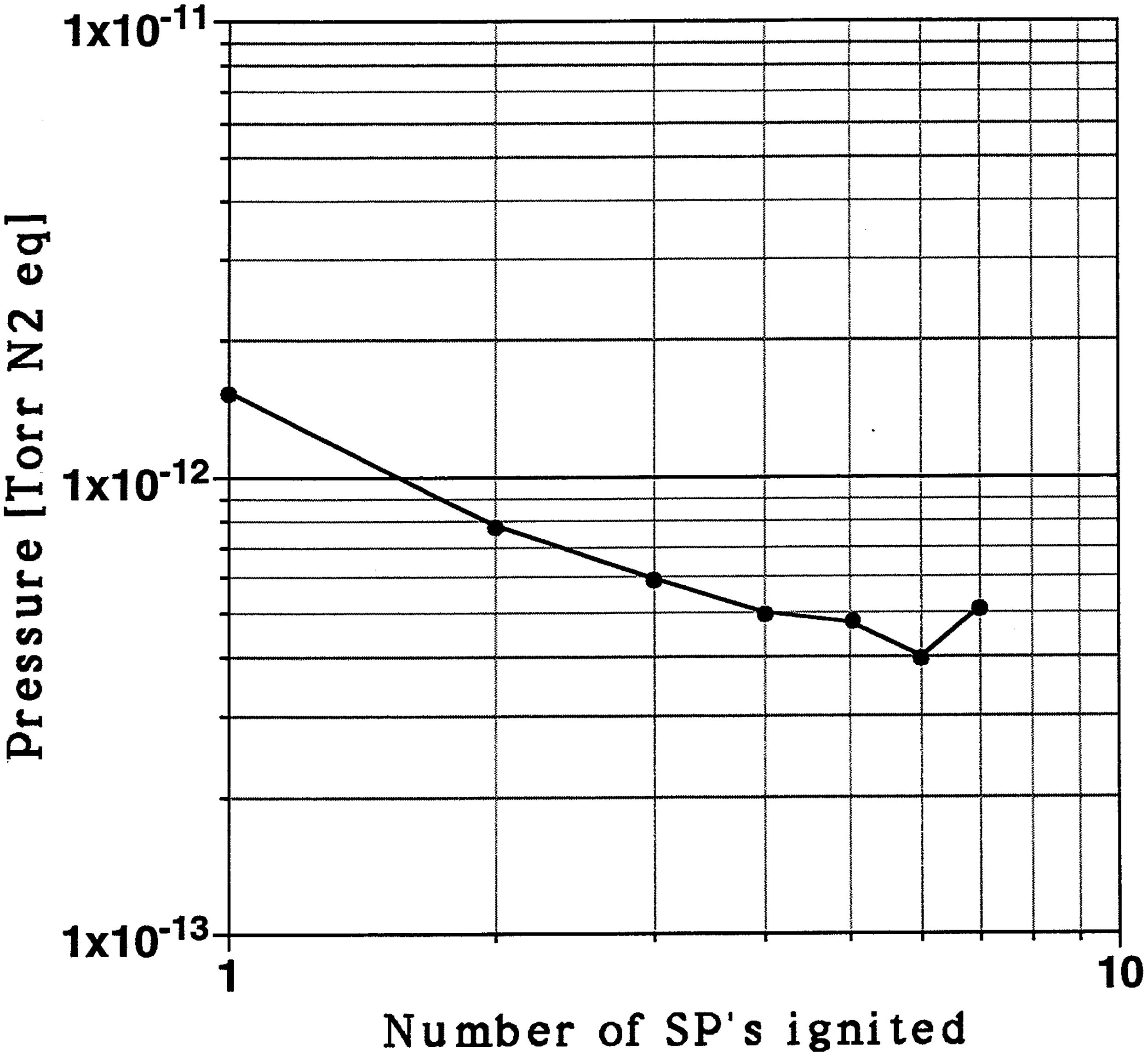
1x10-11
1x10-12
1x10-13
Pressure [Torr N2 eq]
1
10
Number of SP's ignited

Fig. 4