THE LIFE TIME CHARACTERISTICS OF NEG PUMP

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Abstract

We measured the equilibrium pressure and outgassing rate in order to examine the life time characteristics of NEG pump for several times air exposure cycles. The degrading rate of NEG pump for nine times air exposures was small.

1 Introduction

Non-evaporable getters(NEG) pumps have been applied to the accelerator and the nuclear fusion experimental devices to get the ultra high vacuum. The NEG pumps are higher in pumping speed par unit volume and robuster for the fluctuation of the magnetic field than ion pumps.

The NEG pumps are planned to apply the large accelerator in next step i.e. ESRF [1] and APS [2]. Since the accelerator is not yet industrial products but the experimental device, the NEG pumps built in the accelerator have experience of air exposure in many times for maintenance. Consequently we must pay attention to contamination of the NEG pumps.

Our final goal is to find the way of procedure for the accelerator maintenance to protect against the contamination of the NEG pump. In the first step, we experimentally examined how the pumping speed performance degrades by air exposure cycle.

2 Experimental setup

The experimental setup is schematically shown in Fig.1. NEG pump was installed in the main vacuum test chamber made from SUS-304 which was evacuated by the turbo molecular pump (TMP) through the orifice and the narrow duct. The total vacuum pressure was measured by two ionization gauges (nude B-A type) attached to the vacuum test chamber and to the TMP head. The partial residual gas pressure was measured by the mass spectrometer attached to the vacuum test chamber.

The pumping speed of the vacuum test chamber was calculated from the conductance of the orifice and the narrow duct. The diameter of the orifice was equal to 12 mm. The inner diameter and the length of narrow duct were equal to 38 mm and 300 mm, respectively. The pumping speed was equal to 3.1 l/s in calculation.The inner diameter and the length of vacuum test chamber were equal to 148mm and 300mm, respectively.

The NEG pump was St707 GP100W cartridge type supplied with Saes Getters Corporation. The material of St 707 is Zr-V-Fe alloy and can sorb the gases after the activation at 300°C-500°C. The nominal pumping speed is 200l/s for H_2 and 75l/s for CO.

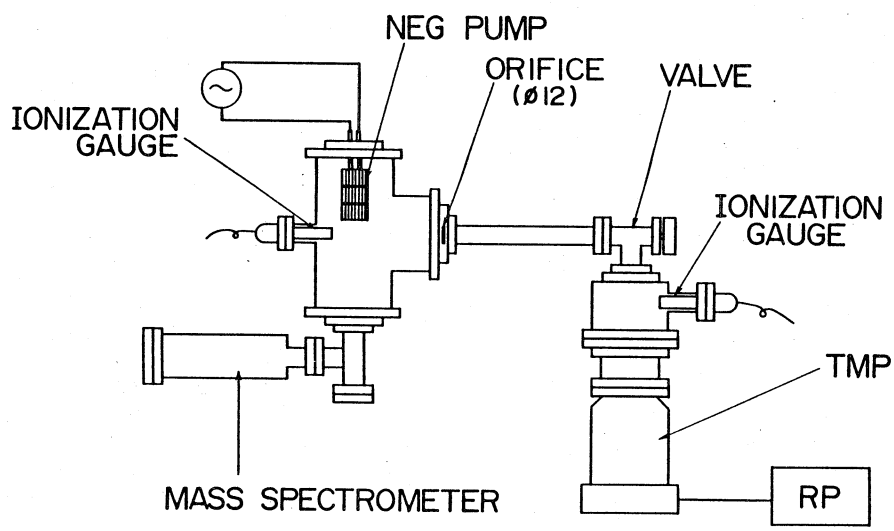

Fig.1 Experimental setup

3 Experimental procedure

In order to evaluate the net pumping speed of NEG pump, the background outgassing rate was measured without NEG pump. The outgassing rate was obtained by the following equation,

$$Q = S(P_1 - P_2), \tag{1}$$

where Q is the outgassing rate in unit of $torr \cdot l/s$, S is the pumping speed which was equal to 3.1 l/s calculated by the conductance, P_1 and P_2 are the pressure of the vacuum test chamber in which NEG pump was installed and the pressure of the TMP head respectively. Then the outgassing rates were 1.1×10^{-7} at $93°C$ and 1.4×10^{-8} at $51°C$.

The air exposure operation was carried out according to following procedures:

1) Expose the NEG pump to the air for an hour,

2) Evacuate the air and bake the chamber at $180°C$ for four hours with ribbon heater typically,

3) Activate the NEG pump at $360°C$ for two hours, or at $420°C$ for an hour. In both cases the activation rate reaches 100%.

These air exposure operations were repeated many times to examine the life time characteristics. The operational parameter for each air exposure operation is shown in table 1. The humidity when the NEG pump was exposed to the air was 40%-50 %.

Table 1 The list of the air exposure cycle.

OPERATION NUMBER	EXPOSURE TIME (hours)	BAKING TIME (hours)	BAKING TEMP. (° C)	ACTIVATION TIME (hours)	ACTIVATION TEMP. (° C)
1	LONG	30	150	2	360
2	43	144	150	2	360
3	1	20	180	2	360
4	1	20	180	2	360
5	1	4	180	1	420
6	1	4	180	1	420
7	1	4	180	1	420
8	1	4	180	1	420
9	1	4	180	1	420

4 Results

The change of total pressure after the activation is shown in figure 2. The pressure was measured since the time when heater for activation of NEG pump was off. The measured pressure was plotted only odd times. This figure indicated that the pressure was higher than that obtained by previous operation. This result suggested that since the equilibrium pressure was obtained after about seven hours, the evacuating time was sufficient enough to evaluate the outgassing rate.

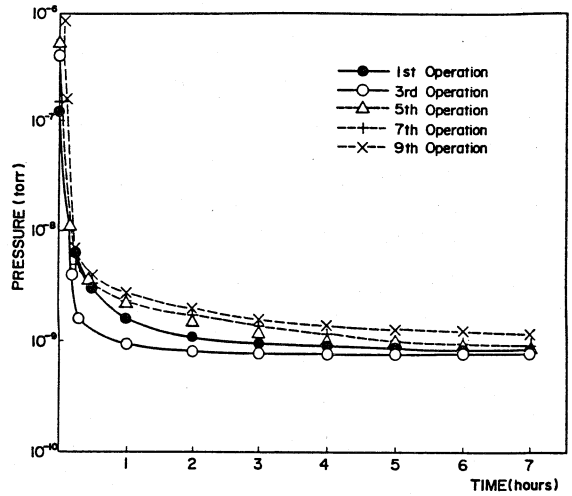

Fig.2 Change of total pressure

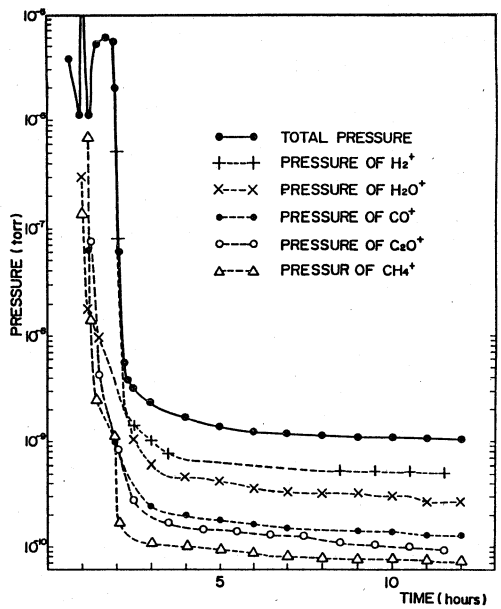

Fig.3 Typical change of partial pressure. This example is refered to 8th operation. Outgassing rate of H_2 was increased with the NEG material temperature, and other gases were reduced as time passes.

Main residual gases were observed to be H_2, CH_4, H_2O, CO, CO_2 by the mass spectrometer installed in the vacuum test chamber. The typical changes of partial pressure were shown in figure 3. The partial pressure was measured since the time when NEG heater was on. The partial pressure of H_2 was dominant in the residual gases during the activation, and other gases were reduced as time passes.

This is the evidence the sorption mechanism of H_2 is different from that of other gases. Since H_2 gas is adsorbed on the surface of NEG material, its outgassing rate is increased with the material temperature. Other gases are absorbed and diffuse into the NEG material. Therefore, once the gases are absorbed in the bulk of the NEG material, they don't get out from it [3]. Whenever the NEG material is heated, its surface becomes active to get in the gases.

5 Discussion

The degrade of the pumping speed will be discussed considering the temperature dependence of the outgassing rate. The outgassing rate Q depends on the temperature T as following equation, [4],

$$Q = A\exp(K/T). \tag{2}$$

Substituting Q and T obtained experimentally in section 3 into the equation (2), the coefficients were solved to be $A = 2.59\times10^{-1}$ and $K = 5.37\times10^{3}$.

The pumping speed S_{NEG} of the NEG pump can be obtained by the following equation,

$$Q = S_{NEG}P_1 + S(P_1 - P_2). \tag{3}$$

The pumping speed of the NEG pump for each operation is obtained in equation (3) as the pressure of test vacuum chamber becomes equilibrium state after seven hours. Calculated results were summarized in table 2.

The degrading rate R is presented in following eq.(4),

$$S_{NEG}P_1 = S_0(1-R)^n, \tag{4}$$

where n is the number of times of air exposure and S_0 is the initial pumping speed of NEG pump.

The degrading rate was not more than 5% for 3rd-9th operations. We neglected 1st and 2nd operations, because the condition of air exposure cycle was different from other operations.

Table 2 The pumping speed of NEG pump for each operation obtained in eq.(3)

OPERATION NUMBER	P 1 (torr)	P 2 (torr)	TEMP. ° C)	outgas (l/s)	S_{NEG} (l/s)
1	8.5E-10	5.2E-9	28.0	4.6E-9	21.0
2	1.1E-9	3.7E-9	27.0	4.3E-9	11.2
3	7.8E-10	3.8E-9	24.3	3.7E-9	16.5
4	7.8E-10	3.8E-9	20.0	2.8E-9	15.4
5	8.9E-10	4.9E-9	20.0	2.8E-9	16.9
6	1.0E-9	4.4E-9	25.8	4.0E-9	14.4
7	9.7E-10	4.4E-9	20.8	3.0E-9	13.9
8	1.1E-9	5.7E-9	23.1	3.4E-9	15.9
9	1.2E-9	5.7E-9	29.1	4.9E-9	15.5

6 Conclusion

We observed the degrading rate of NEG pump for several times air exposure cycle.The operating pressure was the order of $10^{-10}torr$. The performance of NEG pump didn't deteriotate so much for nine times air exposures.

The pumping speed of NEG pump was measured for various gases. The difference of evacuating process between H_2 and other residual gases was recognized experimentally.

References

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