MEASUREMENTS OF WALL CONDITIONING RATE AT URAGAN-2M

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An experiment on chamber RF cleaning for 12 hours a day during 2 weeks with the subsequent vacuum pumping out was carried out. The plasma was produced by the UHF generator with the frequency of 2.4 GHz. Afterwards, the VHF generator working at the frequency of 132 MHz in a continuous mode was turned on and continued to work independently. The process of wall conditioning involved filling the chamber with H_2 under the pressure range inside the chamber of $(1.8…2.0)\cdot10^{-4}$ Torr. During the process of radio-frequency (RF) chamber cleaning the pumped out gas was condensed on the cryogenic trap surface. Afterwards the trap was cut off, heated up and the gas pressure P_g inside the cut off trap chamber was measured. The P_g dependence on both discharge power and condensation time period is analyzed. As a result of the RF cleaning the P_g pressure was reduced by 4…5 times. The vacuum pumping out speed was measured when filling the vacuum vessel with propane and nitrogen.

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INTRODUCTION

Uragan - 2M is a medium size stellarator with the reduced ripples. It is characterized by the torus major radius R=170 cm, the plasma minor radius r_p<24 cm, and by the toroidal magnetic field B_0 < 2.4 T [1].

The chamber is made of stainless steel. The chamber volume is 3.88 m^3, the volume occupied by the plasma is 1.48 m^3. According to the calculations, the total chamber and drainage branch pipes volume is 4.2 m^3. Uragan-2M chamber is pumped out by 3 turbo-molecular pumps. There is a cryogenic trap in the input branch pipe of one of the pumps.

DESCRIPTION OF THE EXPERIMENT

It is known that under RF cleaning CO, H_2, H_2O, CH_4 volatile species are found in the pumped out gases [2]. And when cooling the cryogenic trap with liquid nitrogen, only some of these gases will condense at its surface [3].

An experiment on chamber RF discharge cleaning for 12 hours a day during 2 weeks with the subsequent vacuum pumping out was carried out. The plasma was produced by the UHF generator with the frequency of 2.4 GHz. Afterwards, the VHF generator operating at the frequency of 132 MHz in a continuous mode was turned on and continued to work independently. The very high frequency generator is based on "GI-4A" tube according to the single-cascade generator schema and operates in continuous mode at frequencies 132…136 MHz. The anode voltage varied from 2.5 to 3.5 kV. The generator is connected to the frame-type antenna with water cooling.

The RF wall conditioning made in atmosphere of hydrogen (H2) in the pressure range inside the vacuum chamber of $(1.8…2.0)\times10^{-4}$ Torr, magnetic field is in the range 200…600 G.

The effectiveness of such cleaning was estimated by the following method. During the process of radio-frequency (RF) chamber cleaning the pumped out gas is condensed on the cryogenic trap surface. Afterwards the trap was cut off from the vacuum chamber and heated up. The volume of the cut-off segment is about 52 l, the volume of cryogenic trap is 2.7 l, the condensation surface is 0.105 m^2.

Along with the trap surface temperature increase the pressure inside the cut off trap chamber was increasing due to condensate evaporating from the surface.

The gas pressure Pg in the cut-off segment after the trap heating depends on the amount of gas, which was pumped out of the vacuum vessel and condensed on the trap surface.

Fig. 1 shows that the more generator power during RF discharge and the longer condensation period are – the larger the P_g gas pressure is. The effectiveness of vacuum vessel wall conditioning method could be estimated by the monitoring of changes in P_g values.

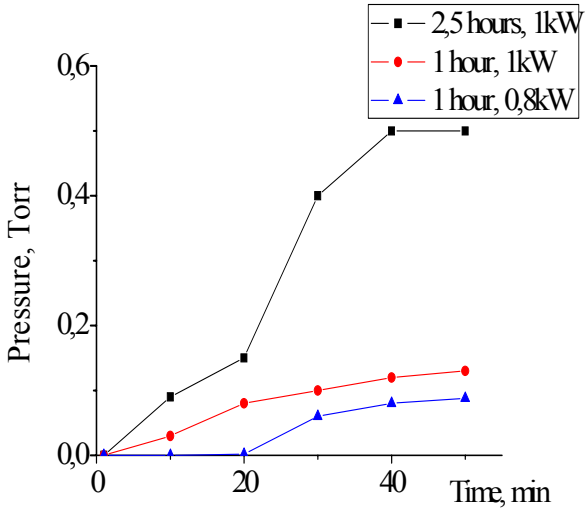

Fig. 1. The P_g gas pressure inside the closed trap during the heating

At the first stage of the experiment method functionality was checked and its sensitivity was defined.

The P_g pressure not more than $5 \cdot 10^{-1}$ Torr was achieved experimentally by changing the duration of 'exposing' (i.e. the condensation time). The pressure was measured by the thermocouple pressure-gauge. It was experimentally shown that this method allows to keep track of quantitative changes of the wall conditioning process. Besides, the duration of 'exposing' must be around 1 hour both for VHF and UHF modes. 1 hour time period was, therefore, chosen for further experiments.

RESULTS OF EXPERIMENTS

The same method was used for measuring a wall outgassing along with H_2 filling. The P_g in this case was 0.003 Torr, which is almost one thousand times less than under different variations of RF wall conditioning.

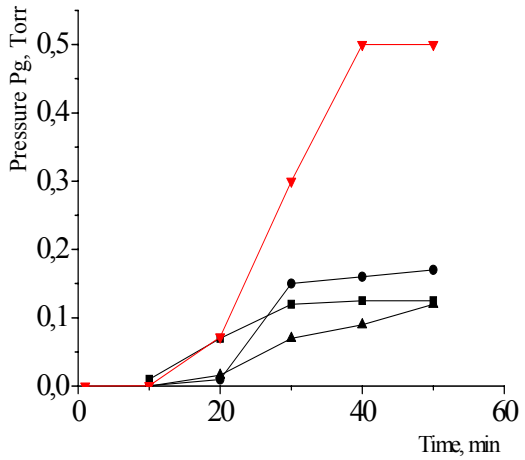

Fig. 2. The experiment on VHF discharge cleaning. Red line – the P_g pressure before the experiment. Black lines – the last three days of the experiment

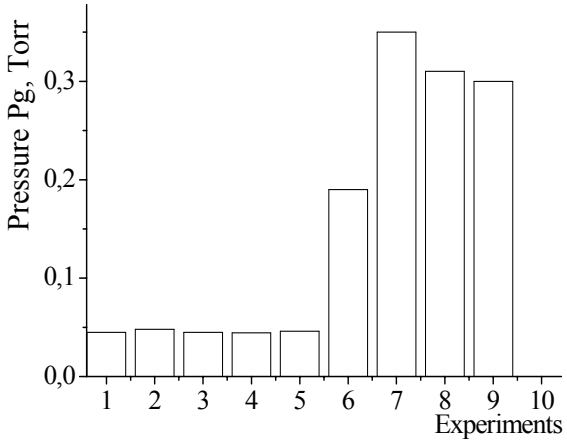

Fig. 3. Propane pressure – after heating up the trap. Experiments №1-5 under Pvv=$1 \cdot 10^{5}$ Torr, № 6 under Pvv=$5 \cdot 10^{-5}$ Torr, №7…9 under Pvv=$1 \cdot 10^{-4}$ Torr

At the next stage of the experiment the method was verified for hydrocarbons. Propane (C_4H_{10}) was chosen as a test gas. The method of constant pressure [3] was used to define the speed of propane filling the chamber under the simultaneous pumping out by three pumps (when the trap is refrigerated). The measurements have shown that the gas pumping speed was 42 l/s under the P_{vv} chamber pressure of $1 \cdot 10^{-4}$ Torr, and Q=53 l/s when $P_{vv}=1 \cdot 10^{-5}$ Torr. This gas pumping speed Q values matched with the P_g gas pressure values of 0.3 Torr and 0.05 Torr correspondingly (see Fig. 3).

The same method was applied to estimate the pumping speed for nitrogen.

Experimental results for VHF conditioning and propane pas fuffing

Parameters	Pressure after heating of trap, P_g Torr	Gas pumping out speed, l/s	Pressure in the vacuum vessel, P_{vv} Torr
VHF (Start)	0.6		$(1.8…2.0)\times10^{-4}$
VHF (Finish)	0.12…0.16		
UHF	0.2…0.3		
Propane	0.3	42	1.0×10^{-4}
Nitrogen	0.003	245	

The main results of the experiment are given in the Table. On the 10th day of the experiment on continuous VHF discharge the P_g pressure was reduced by 4…5 times (0.6 and 0.12…0.16 Torr) (Fig. 2). At the initial stage of the experiment the P_g values were larger than at the stage of adding propane. This fact shows that the gas pumping out speed under such modes of wall conditioning is insufficient.

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ИЗМЕРЕНИЕ СКОРОСТИ ЧИСТКИ КАМЕРЫ УРАГАН-2М

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Был проведен эксперимент по чистке стенок камеры в течение 2 недель по 12 часов в день с последующей откачкой камеры. Плазма создавалась СВЧ-генератором с частотой 2.4 ГГц и затем включался УКВ-генератор, работающий на частоте 132 МГц в непрерывном режиме, который в дальнейшем работал самостоятельно. Чистка производилась с напуском водорода в диапазоне давлений в камере $(1.8...2.0)\times10^{-4}$Торр. В процессе чистки камеры УКВ-разрядом производилась конденсация образовывающегося внутри камеры газа на охлажденную поверхность азотной ловушки. Затем ловушка отсекалась от насоса и от камеры установки, проводилось ее отепление и измерялось давление газа P_g в отсеченной камере ловушки. Показана зависимость P_g от мощности разряда и длительности конденсации. По результатам эксперимента отмечено снижение значений P_g в 5...6 раз. Проведено измерение скорости откачки вакуумной системы для пропана и азота.

ВІМІРЮВАННЯ ШВИДКОСТІ ЧИЩЕННЯ КАМЕРИ УРАГАН-2М

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Було проведено експеримент з очищення стінок камери на протязі 2 тижнів по 12 годин на день з наступною відкачкою камери. Плазма створювалась НВЧ-генератором з робочою частотою 2.4 ГГц, після цього вмикався УКВ-генератор, що працював на частоті 132 МГц у безперервному режимі, який надалі працював самостійно. Очищення проводилось з напуском водню у діапазоні тиску в камері $(1.8...2.0)\times10^{-4}$ Торр. Протягом процесу чищення камери УКВ-розрядом проводилась конденсація газу, що створюється в камері, на охолоджену поверхню азотного уловлювача. Потім пастка відтиналася від насоса і від камери установки, проводилося її утеплення й вимірювався тиск газу P_g у відсіченій камері пастки. Показано залежність P_g від потужності розряду та тривалості конденсації. За результатами експерименту відмічено зниження значень P_g у 5...6 разів. Проведено вимірювання швидкості відкачки вакуумної системи для пропану та азоту.