RF WALL CONDITIONING AT THE URAGAN-2M WITH USE OF HIGH VACUUM CRYOGENIC TRAP

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The results of evaluating the effectiveness of the vacuum chamber wall conditioning procedure by the use VHF of continuous discharge and RF pulse discharge that were applied either separately or in combination with each other in helium atmosphere at Uragan-2M are presented. The high-vacuum cryogenic traps are enabled in these experiments. Some amount of gas pumped from the vacuum chamber is condensed on the surfaces of cryogenic traps integrated in the input branch pipes of the vacuum system. Periodically, one trap is separated from the chamber and from the pump by vacuum valves and warmed up what led to release of the condensed gases into the enclosed volume. The value of pressure P_g inside this volume is proportional to the amount of pumped gas and, consequently, to the effectiveness of the wall conditioning process. It was found that the value P_g in the combined VHF + RF discharge is 2-3 times higher than in the case of using only pulsed RF discharge.

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INTRODUCTION

A staged wall conditioning was carried out at the stellarator Uragan-2M with major radius R=170 cm and plasma minor radius r_{pl}<22 cm [1]. At the first stage after closing all ports, the vacuum chamber was heated up to 60…65 °C during twenty days. During last two days of heating process, the VHF wall conditioning (f_g=135 MHz) of vacuum chamber by continuous discharge in hydrogen was added [2]. At the third stage Kaskad-1 pulse RF generator was used together with the VHF generator for the discharge sustaining.

The details of conditioning by VHF discharge are described in Ref. 3. The wall conditioning was carried out by the VHF generator at the frequency of 132 MHz and power of about 2 kW. Additionally, the continuous generator at the frequency of 4.7 MHz and the power of around 1 kW is used. During the wall conditioning, the steady magnetic field B was 400…500 G.

EQUIPMENT OF THE EXPERIMENT

The effectiveness of conditioning was estimated by the following method.

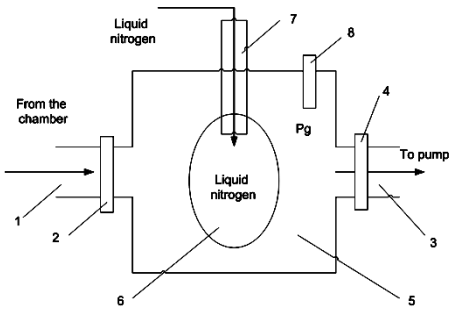

Fig. 1. The scheme of the experiment: 1 – pipeline from the chamber; 2 – vacuum valve №1; 3 – pipeline to the pump; 4 – vacuum valve №2; 5 – the cut off volume; 6 – container for liquid nitrogen, the pumped gases are condensed on its surface; 7 – pipe for inputting cryogenic liquid; 8 – P_g pressure sensor

Some amount of gas from the vacuum chamber 1 (Fig. 1) is condensed on the surface of one of the cryogenic traps 6 which is located in the input branch pipe 3 of the vacuum system pump. Periodically this trap is cut off from the chamber and from the pump by the vacuum valves 2 and 4, and heated up inside the volume 5. The condensation time (the exposition) was either 1 hour or 30 minutes. Then the pressure P_g inside this volume is a guide to the amount of pumped gas – i.e., can characterized the effectiveness of the wall conditioning process. This method is described in [2] in detail.

The VHF generator is based on a GU-4B tube, which is an air-cooled vacuum triode. The single-stage oscillator scheme with a common grid was used. The output frequency could be tuned within the range of 130…140 MHz. The power output is about 2…4 kW. The design of RF circuits is based on the so called “air coaxial”. The feedback signal is received from the loops made of copper straps located in anode cylindrical cavity. The feedback magnitude is controlled by adjusting the distance between the anode cavity and the surface of feedback straps, as well as by selecting the number of the loops. The RF power is taken off from an anode cavity into the coaxial cable through a coupling capacitor. It also serves as a matching component of the anode cavity to a loaded feeder line. The RF power transmission line to the antenna consists of 2 feeders of type RK-50-11-13, connected in parallel, with wave impedance is 25 Ohm. The directional coupler is placed at the output of the generator. The power of the generator was controlled by the value of the cathode current. It was varied in the range 0.82.7 A under various antenna loads, while the anode voltage was 4 kV. The generator is connected to the small frame antenna which is described in Ref. 2.

MEASUREMENT RESULTS

Fig. 2 shows variations in P_g, which is in proportion to the amount of pumped gas, during the first stage of the wall conditioning, the vacuum chamber baking. Measurement results show that gas emission from the

walls reaches its peak after heating the chamber during 20…24 hours.

Fig. 3 demonstrates reducing trend of the amount of pumped gas during the second day of wall heating. The measurements were carried out under the exposition of 30 minutes. The amount of pumped gas is noticeably decreased (P_{g1}=0.044 Torr and P_{g3}=0.027 Torr) in comparison to the previous day, when P_{g3}=0.4 Torr, which could be explained by the decrease of the amount of residual gas in the vacuum chamber.

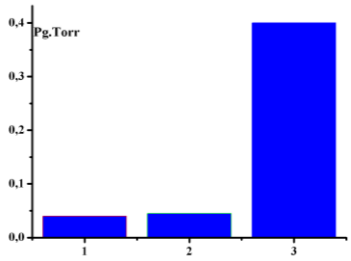

Fig. 2. P_g pressure values measured during vacuum chamber baking (exposition is 1 hour): 1 – after 3 hours; 2 – after 6 hours; 3 – after 24 hours since the baking starts

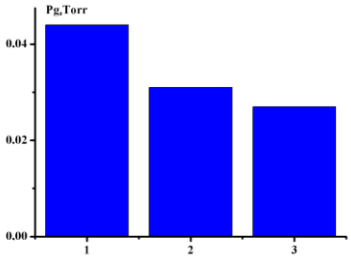

Fig. 3. P_g pressure values (exposition is 30 min): 1 – 27 hours from the beginning of baking; 2 – 28 hours; 3 – 30 hours

Thereafter the stage of simultaneous VHF wall conditioning and wall heating began. Fig.4 shows a substantial increase in P_g values during the VHF conditioning (2). The value of P_{g1}=0.18 Torr during the VHF conditioning and heating is more than 10 times higher, than in the mode of baking only P_{g2} = 0.013 Torr.

The RF wall conditioning of the chamber in helium atmosphere was carried out at the Uragan-2M stellarator. The effectiveness of the conditioning was estimated by the same method as described above.

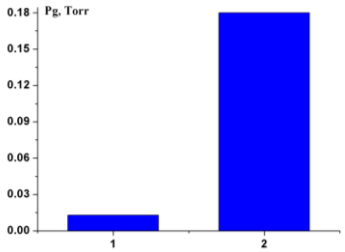

Fig. 4. P_g pressure values measured at vacuum chamber baking (1) and at the simultaneous baking and VHF conditioning in continuous mode (2)

Under simultaneous operation of the Kaskad generators [4] and the VHF generator produced helium plasma, the value of P_g (Fig. 5) has decreased by 2.5 times (from 0.18 to 0.072 Torr) after 10 days of conditioning.

Fig. 6 demonstrates that the effectiveness of conditioning in helium atmosphere is 2…3 times higher for the combined VHF+RF discharge (1 and 2) than for the pulsed RF discharge only (column 3).

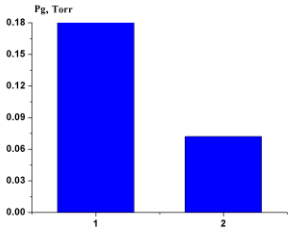

Fig. 5. P_g pressure values during 10 days of conditioning: 1 – after the 1st day of conditioning; 2 – after the 10th day

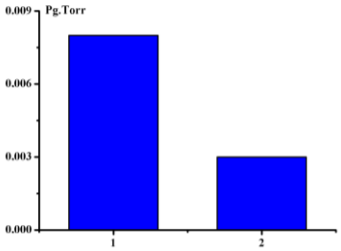

Fig. 6. P_g pressure values during the operation of different generators: 1 – VHF+RF discharge; 2 – RF discharge only

It is necessary to mention the fact that the Kaskad-1 antenna loading is higher when operating together with the VHF generator [5].

RGA data shows (Fig. 7) that after the 10 day conditioning the content of the following gases was decreased: CO_2 by 1.6 times, CH_4 from 10^{-9} to almost 0, O_2 – by 1.1 times, C_3H_8 dropped to 0. At the same time the level of NH_3 and He was increased in 1.5 times, the amount of water was increased in 1.5 times too.

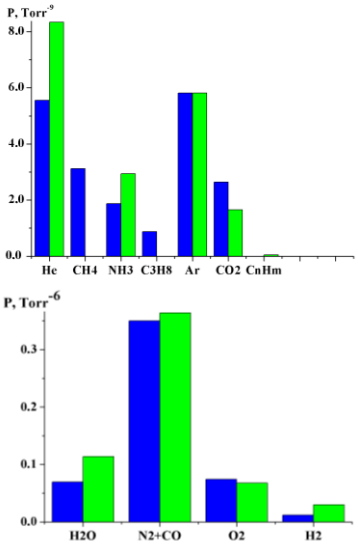

Fig. 7. RGA data obtained as a result of the 10 day RF conditioning

Fig. 8 shows the variations in gas partial pressures inside the chamber after 60 and 80 minutes of wall

conditioning under the continuous mode of VHF generator in comparison to the beginning of wall conditioning (green color). After working for 1 hour the amount of CH_4, NH_3, C_3H_8, Ar, CO_2 was increased and then dropped (except for the CO_2). The amount of water was also decreased.

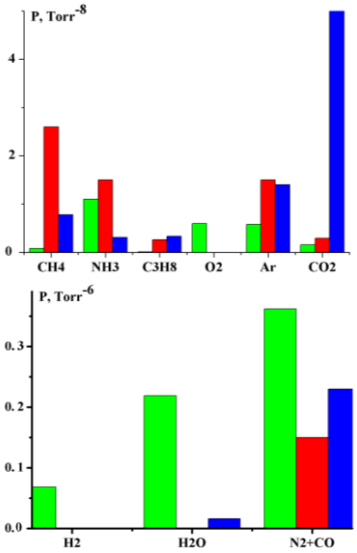

Fig. 8. Comparison of partial pressures of gases during the operation of VHF generator. Green color – before the conditioning. Red – 60 minutes after the beginning of conditioning. Blue – 80 min after the beginning of conditioning

CONCLUSIONS

Based on the above it is arguable that the combination of RF wall conditioning and chamber wall baking for at least 2-3 days has a beneficial effect on the wall conditioning process at Uragan-2M stellarator. The combination of continuous VHF discharge and RF pulses increases the amount of pumped gas in about 2-3 times. Under the VHF discharge carbohydrates, CO_2 are actively formed inside the chamber. The 10 day conditioning with helium decreased the amount of gas pumped from the chamber by 2.5 times.

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ВЧ-ЧИСТКА В СТЕЛЛАРАТОРЕ УРАГАН-2М С ИСПОЛЬЗОВАНИЕМ КРИОГЕННОЙ ЛОВУШКИ

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Приведены результаты ВЧ-чистки в стелларатоpе Ураган-2М с использованием УКВ непрерывного разряда в атмосфере гелия. При этом часть откачиваемого газа конденсировалась на криогенную ловушку. Процесс чистки контролировался измерением давления газа $P_г$ в отсеченном объеме с ловушкой после ее отепления. Значение $P_г$ пропорционально количеству откачиваемого газа. Обнаружено, что количество сконденсированного на ловушке газа при комбинированном УКВ+ВЧ-разряде в 2-3 раза выше, чем в случае использования только импульсного ВЧ-разряда.

ВЧ-ЧИСТКА В СТЕЛАРАТОРІ УРАГАН-2М З ВИКОРИСТАННЯМ КРИОГЕННОЇ ПАСТКИ

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Наведено результати ВЧ-чистки в стелараторі Ураган-2М з використанням УКХ безперервного розряду в атмосфері гелію. При цьому частина відкачуваного газу конденсувалась на криогенну пастку. Процес чищення контролювався за допомогою вимірювання тиску газу $P_г$ у відсіченому об`ємі з пасткою після її отеплення. Значення $P_г$ пропорційно кількості відкачуваного газу. Виявлено, що кількість сконденсованого на пастці газу при комбінованому УКХ + ВЧ-розряді в 2-3 рази вище, ніж у випадку використання тільки імпульсного ВЧ-розряду.