MASS-SPECTROMETER DIAGNOSTICS COMPLEX WITH CRYOGENIC NITROGEN TRAP

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The measuring complex with the cryogenic nitrogen trap [1] was created to monitor the gas composition in the stellarator Uragan-2M chamber. The complex provides several gas sampling options for the research: directly from the vacuum chamber, and condensed gas from the cryogenic trap chamber after its being heated. A new measuring cryogenic trap with its own valves was developed to implement the second method. It is necessary to provide such a state of the internal vacuum surfaces of the complex so that the background gas emission from the walls of the measuring vacuum chamber does not lead to the measurement errors in order to obtain more accurate mass spectral data. The heating of the chamber walls and continuous RF discharge at frequencies of 6…8 MHz and the power of 1 kW without a magnetic field was planned to used for this purpose. Two RF antennas, rod and planar, were designed.

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Various gases are generated during high-frequency cleaning process in the vacuum chamber of the stellarator. These gases can partially condense on the surface of the cryogenic trap. The more gas is generated during the cleaning process, the more of it will condense on the cooled surface of the trap. It is necessary to condense the gas for a certain time to determine the amount of condensed gas. Then the trap is cut off from the chamber and from the pump and is heated in the closed volume. Since the trap heating volume is constant, it is possible to judge the amount of condensed gas and consequently the amount of gas generated during the cleaning process by the value of the pressure P_g measured in it. As the cleaning time increases, the speed of gas creation in the chamber should decrease. We can control the cleaning process through monitoring of pressure P_g. This process is entirely described in details in previous papers [1, 3].

One of the turbo-molecular pumps of the vacuum system had to be cut off from the main pipeline of the stellarator Uragan-2M, to heat P_g trap and measure the pressure.

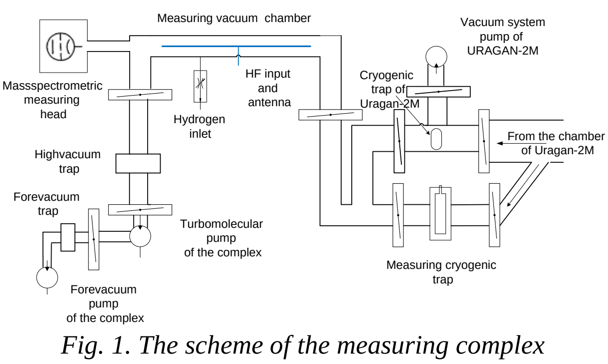

Fig. 1. The scheme of the measuring complex

This affected the productivity of the whole stellarator pumping system and led to the pressure change in Uragan-2M chamber during the experiments. To avoid such situation, a new measuring trap with its own pipes and valves was constructed on the basis of the comparative estimation of the vacuum flows in the operating and measuring channel of the vacuum system shown in Fig. 1 in the stationary mode. Since these channels are connected in parallel, and the pressure differences between the inlet and outlet channels are the same, the ratio of the fluxes in these channels will depend only on their conductivity, and will be equal to the ratio of the channels vacuum conductances. The following values of the corresponding channels conductivity were calculated:

– working channel – 0.75 m^3/s;

– measuring channel – 0.0243 m^3/s.

This means that the calculated gas flow in the measuring channel is 30 times less than in the working channel. Therefore, the same amount of gas can be condensed in the cryogenic trap. To obtain a sufficient amount of gas for mass spectrometric measurements, it is necessary to increase the surface area for the condensation of the pumped gas. The surface area of the cryogenic trap pipe is 932.58 cm^2, the surface area of the trap is 542.592 cm^2. The volume of the heated trap chamber is 0.006585 m^3, the volume of the trap itself is 0.000675 m^3. The ratio of the chamber and the trap volumes has decreased almost 5 times. Those the density of gas molecules flow per unit of cooled area has decreased, and the condensation probability of gas molecules on its surface has increased.

The creation of a new measuring trap made it possible to investigate both gases after their condensation on the trap, gases directly from the stellarator chamber, and also gases that passed the working trap.

The diagnostic complex consists of: a vacuum pumping system; a system selecting the gas to be studied; RF cleaning systems; hydrogen inlet system in the cleaning mode; measuring system. The pumping system contains a fore-vacuum pump 2HBP-5DM, which is connected to the turbomolecular pump TMN-500 through the nitrogen trap LAF-32 and the vacuum gate system. The high-vacuum nitrogen trap is located in front of the vacuum chamber in the inlet pipe of the TMN-500 pump. This system allows you to achieve a pressure of $1 \cdot 10^{-7}$ Torr. Vacuum chamber volume of 46800 cm^3 consists of three communicating sections. The first section with a diameter of 200 mm and a length of 500 mm is located vertically and contains a block of PMI-2 lamp and a PMO-4C lamp. The second section, with diameter of 140 mm and length of 1620 mm, is connected to the gas extraction system. The gas sampling system contains the system of vacuum gates that connects various sources of the test gas: the measuring nitrogen trap, and the stellarator chamber. The antenna for RF cleaning is installed in the second section of the vacuum chamber. Two types of antennas were made. The first is a rod with diameter of 10 mm and the effective length (length inside the section) of 70 mm, and the second is a symmetrical plate (length 800 mm, width 20 mm, thickness 2 mm). Antenna is connected through a vacuum input device to the parallel LC-circuit, which loads the RF generator. The circuit matches the RF generator with the antenna, and simultaneously provides the increase in RF voltage on the antenna to ensure the reliable discharge in the vacuum chamber. There is an observation window for visual control of the high-frequency discharge opposite the antenna input. The NRP-1.6 flow regulator is between the RF antenna input and the first section. It serves as the inlet of working gas (hydrogen), and allows to regulate the pressure in the vacuum chamber of the measuring path in the range of $(760\ldots7) \cdot 10^{-7}$ Torr. The third section is vertical, it is 140 mm in diameter and 400 mm in length. It connects the system for sampling the test gas with the measuring system of the complex. The measuring system consists of three VIT-3 vacuum gauges to control the pressure in various parts of the complex vacuum system and the omegatron meter IPDO-1 of the test gas partial pressures and the temperature control of the vacuum chamber wall in the heating mode. Fig. 2 is a photograph of the measuring system.

Fig. 2. Photo of the measuring complex

To achieve the necessary conditions of the diagnostic system purity, a set of measures were carried out from mechanical cleaning, heating the chamber walls to the temperature of about 80 °C, to the continuous RF-cleaning discharge without a magnetic field [2]. Parameters of the continuous RF discharge were: generator frequency $f = 6\ldots8$ MHz, power up to 1 kW and working gas pressure (hydrogen) about $1 \cdot 10^{-2}$ Torr. Two antennas (rod and planar) were tested. The plasma discharge existed locally near the antenna and its dimensions changed in proportionally to the changes of the input RF power (Fig. 3).

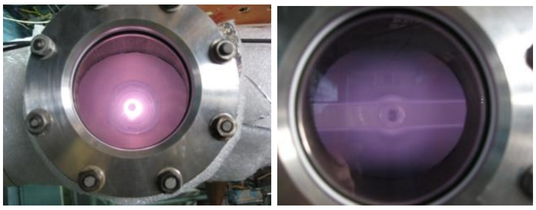

Fig. 3. The photo of high-frequency discharge creted with the rod (left) and planar (right) antenna.

Two circuits were used for the oscillatory circuit connection (Fig. 4). The strong heating of the antenna itself was noticed while using the grounded circuit (this is also noticeable on the photo, see in Fig. 2 on the left), which led to the high-voltage antenna insulator and the adjacent section of the vacuum chamber heating. The circuit was used with the separating capacitor C_p, which disconnects the antenna from the RF generator through direct current to eliminate this effect and prevent antenna bombardment by electrons, which causes heating of the antenna itself.

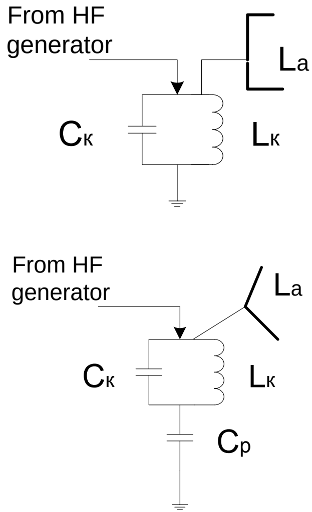

Fig. 4. Wiring diagram of the oscillating antenna. Below is the ungrounded antenna circuit variant

High-frequency cleaning was not carried out at this stage. Only antenna connection schemes and generator modes were worked out. Cleaning of the vacuum chamber was carried out by heating its walls. Fig. 5 shows the data of residual gases partial pressures measurements in the vacuum volume of the complex after heating the chamber for 5 days for 6 hours with subsequent evacuation. The diagrams shows that the water vapor pressure, CO_2 decreased almost 3 times, the hydrocarbon group – 2 times as a result of the chamber heating.

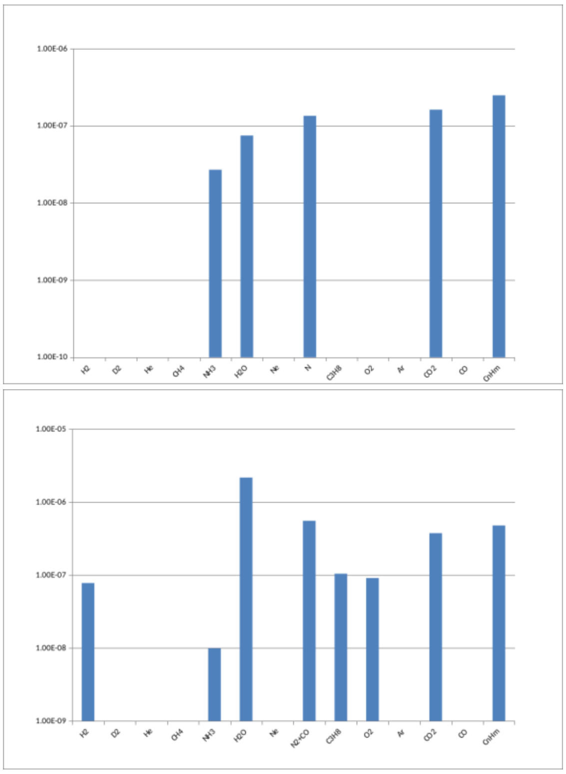

Fig. 5. OPPM data after 5 days of chamber cleaning through heating

REFERENCES

1. V.B. Korovin, D.I. Baron, A.V. Lozin, M.M. Kozulya, V.Ya. Chernichenko, E.D. Kramskoy, V.K. Pashnev, M. Mozetič. HF wall conditioning at the URAGAN-2M using high vacuum cryogenic trap // *Problems of Atomic Science and Technology. Ser. "Plasma Physics"*. 2015, № 1, p. 53-55.
2. A.V. Lozin, V.E. Moiseenko, M.M. Kozulya, E.D. Kramskoj, V.B. Korovin, A.V. Yevsyukov, L.I. Grigor'eva, A.A. Beletskii, A.N. Shapoval, M.M. Makhov, A.Yu. Krasyuk, D.I. Baron and Uragan-2M Team. Continuous wall conditioning vhf discharge without magnetic field in a toroidal device // *Problems of Atomic Science and Technology. Ser. "Plasma Physics"*. 2016, № 6, p. 60-63.
3. D.I. Baron, V.B. Korovin, E.D. Kramskoy, S.M. Maznichenko, S.I. Solodovchenko, V.Ya. Sherni-shenko, A.F. Shtan. Measurements of wall conditioning rate at Uragan-2M // *Problems of Atomic Science and Technology. Series "Plasma Physics"*. 2013, № 1, p 21-23.
4. V.F. Gaidukov, V.P. Kolesnik, L.V. Litovchenko, V.V. Kolesnik, D.V. Slyusar. *Design and calculation of vacuum systems of test benches and technological installations*. Kiev: "Millennium", 2009, 172 p.
5. L.N. Rozanov. *Vacuum technology* / 2nd Ed. M.: "Higher", 1990, 320 p.

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МАСС-СПЕКТРОМЕТРИЧЕСКИЙ ДИАГНОСТИЧЕСКИЙ КОМПЛЕКС С АЗОТНОЙ ЛОВУШКОЙ

С.А. Цыбенко, Е.Д. Крамской, В.Б. Коровин, А.В. Евсюков, А.В. Лозин, В.Е. Моисеенко, Г.А. Холомеев, В.Ю. Грибанов, М.М. Козуля, С.М. Мазниченко, А.Ю. Красюк, Д.И. Барон и команда Ураган-2М

На стеллараторе Ураган-2М был создан диагностический комплекс с криогенной азотной ловушкой [1] для контроля состава газа в камере стелларатора. Комплекс предусматривает несколько вариантов отбора проб газа для исследования: непосредственно с вакуумной камеры и конденсированного газа из камеры криогенной ловушки после её нагрева. Для реализации второго метода была разработана новая измерительная криогенная ловушка со своими клапанами. Для получения более точных масс-спектральных данных необходимо обеспечить такое положение внутренних вакуумных поверхностей комплекса, чтобы утечка фонового газа со стенок измерительной вакуумной камеры не привела к ошибкам в измерениях. Для этого планировался нагрев стен камеры и непрерывного ВЧ-разряда на частотах порядка 6…8 МГц мощностью до 1 кВт без магнитного поля. Были разработаны две ВЧ-антенны: штыревая и пластинчатая.

МАС-СПЕКТРОМЕТРИЧНИЙ ДІАГНОСТИЧНИЙ КОМПЛЕКС З АЗОТНОЮ ПАСТКОЮ

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На стеллараторі Ураган-2М був створений діагностичний комплекс з криогенною азотною пасткою [1] для контролю складу газу в камері стелларатора. Комплекс передбачає декілька варіантів відбору проб газу для дослідження: безпосередньо з вакуумної камери та конденсованого газу з камери криогенної пастки після її нагрівання. Для реалізації другого методу була розроблена нова вимірювальна криогенна пастка з власними клапанами. Для отримання точніших мас-спектральних даних необхідно забезпечити такий стан внутрішніх вакуумних поверхонь комплексу, щоб витік фонового газу зі стінок вимірювальної вакуумної камери не призвів до помилок у вимірах. Для цього планувалося нагрівання стін камери та безперервного ВЧ-розряду на частотах близько 6…8 МГц потужністю до 1 кВт без магнітного поля. Були розроблені дві ВЧ-антени: штирьова і пластинчата.