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# UPGRADE OF MASS-SPECTROMETER DIAGNOSTICS COMPLEX WITH CRYOGENIC TRAP

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The mass spectrometric diagnostic complex on the Uragan-2M stellarator has been upgraded. The design of the vacuum system of the complex has been changed. A system for monitoring the surface temperature of the cryogenic trap and the pressure in the trap chamber during its heating has been installed. A new PRISMA PRO mass spectrometer has also been installed. The first measurements of the dynamics of cleaning the stellarator vacuum chamber during glow discharge cleaning in an argon atmosphere have been carried out.

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## INTRODUCTION

Vacuum chamber walls cleaning of modern fusion devices is important and essential measure for achieving maximal plasma parameters [1, 2]. Hence all modern fusion devices with magnetic confinement utilize different wall conditioning procedures [1, 2]. For instance, stellarator Uragan-2M walls are conditioned with impulse and stationary RF discharges at different frequencies in weak magnetic field [3–5], glow discharge cleaning [6, 7] and combined glow+microwave discharge [8]. The wall conditioning process results control is also an important stage of fusion device preparation sequence.

It was reported, that during LHD stellarator vacuum chamber cleaning the pumped out gases mass-specters included CO, $H_2$, $H_2O$, $CH_4$ and other hydrocarbons [9]. According to generalized data [10], the main residual gas components after different tokamaks vacuum chamber cleaning are $H_2$, $H_2O$, CO, $N_2$, and some hydrocarbons ($CH_4$). The W7X device chamber cleaning showed mass-specters of CO, $H_2$, $H_2O$ and hydrocarbons minor amount [11].

If the liquid nitrogen trap is placed in stellarator or tokamak vacuum chamber space, the gases will partially condense upon the trap surface during plasma discharge cleaning [12]. The cryo-capture method allows to reveal gas mixture composition when condensed gas mixture is heated afterwards. Cryogenic traps are successfully used for qualitative and quantitative gases composition determination [13]. The cryo-capture method is used in manufacturing for gas purity control, like nitrogen filling the high-voltage aerial fuses. Almost all admixtures condense inside the liquid nitrogen trap while passing it except for nitrogen itself. The admixtures are analyzed after trap defrosting when they enter the mass-spectrometer through piezoleak valve in gaseous state [14]. During cryo-trapping assisted mass spectrometry (CTAMS), the researched gases are condensed inside cryogenic trap. Then the trap is continuously gradually heated for caring out precise pressure measurements of the separate gas mass groups, as it is important to know exact gas composition during gas cleaning process [15].

The mass-spectrometer measurement complex with cryogenic trap was developed for Uragan-2M stellarator [16]. The complex was created to study and control gas composition, when it is pumped from device vacuum chamber during and after wall conditioning procedure. The mass-spectrometer measurement complex was modernized. This paper describes the modernized mass-spectrometer measurement complex and presents its first experimental results.

## MASS-SPECTROMETER DIAGNOSTICS COMPLEX WITH CRYOGENIC TRAP

The diagnostic complex is equipped with vacuum pumping system: backing vacuum pump 2NVR-5DM is connected through liquid nitrogen trap LAF-32 and vacuum locks system to the turbomolecular pump TMH-500 [16]. The vacuum system volume is 46800 $cm^3$. The vacuum pumping system can provide pressure down to $10^{-7}$ Torr in the measurement duct. The vacuum duct consists from three sections (Fig. 1). The first section is placed vertically above turbomolecular pump. The second section consists from two parts. The first part is horizontal, diameter 140 mm and length 1620 mm, the second one is vertical, diameter 140 mm and length 400 mm, and can be connected to the Uragan-2M vacuum pumping system and also cryogenic trap output. The third section consists from diagnostic cryogenic trap and vacuum duct connected to the Uragan-2M vacuum chamber. Such vacuum system scheme allows studying gas mixtures both from stellarator chamber directly, gases condensed on diagnostic trap cooled surfaces (after it is heated) and gases that don't condense inside the trap and are pumped freely trough measurement volume ofmass-spectrometer [16].

The trap surface area is 0.0542 m$^2$. The trap chamber volume, where condensed gases are evaporated, is 0.006585 m$^3$. A short periods of gas condensation and trap heating increase measurements responsiveness for on-line vacuum chamber cleaning process control.

The cleaning dynamics control method core point are following. The plasma discharge initiates gas desorption from vacuum chamber walls during cleaning. The gases are pumped from the vacuum chamber through cryogenic trap and condensate upon trap's cooled surface. If the condensation time is fixed, than the condensed gas amount depends from gas volumed that was pumped through the trap under all other constant conditions (pressure, temperature, etc). The cleaner are vacuum chamber walls, the less gases condensate on the cooled surface. According to Avogadro law or Mendeleev-Clapeyron equation, the pressure in closed volume under constant temperature is determined by amount of gas. Hence, to determine condensed gas amount, the trap is isolated with vacuum locks from both sides, and this closed volume is heated. The constant volume of the trap allows to evaluate the condensed gas amount with pressure $P_g$ measured inside it. The whole process is described in details in [16-19].

*Fig. 1. The modernized measurement stand photo (without heat insulation)*

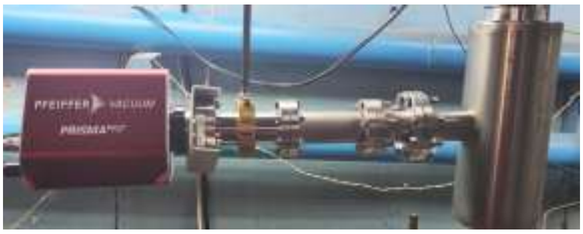

*Fig. 2. Mass-spectrometer PrismaPro photo*

A new compact mass-spectrometer Prisma Pro manufactured by Pfeiffer Vacuum was installed at the stand (Fig. 2). It is a quadrupole system for qualitative and quantitative gas analysis in high and ultrahigh vacuum range and for detecting leaks. The mass-spectrometer functions as follows. The ion source electron beam ionizes neutral gas particles. The high-frequency electrical quadrupole field separates created ions according to their mass to charge ratio. The filtered (separated) ions are detected with Faraday cup or secondary electron multiplier. The detected ion stream is proportional to partial pressure of according gas components. The measurements are carried out at the pressure of $<10^{-4}$ mbar. The mass measurement range [u] is from 1 to 100 units [20].

The vacuum ducts walls heating system was also modernized on this diagnostic complex. This system allows to control vacuum chamber heating up to the temperature of 100$^0$C.

## EXPERIMENTAL RESULTS

The modernized mass-spectrometer measurement complex went through testing. The cryogenic trap measurements were carried out during glow discharge cleaning of Uragan-2M chamber. The cleaning was carried out in argon atmosphere with different pressure. The electrode voltage was $U_e$=270…290 V, the discharge current was $I_e$=0.2 A. Fig. 3 shows pressure ($P_g$) measurements inside trap chamber after its heating.

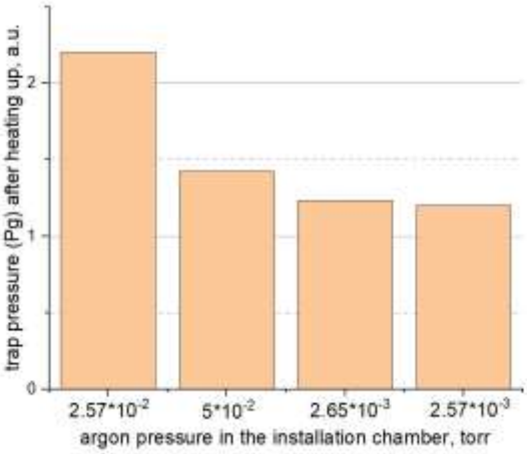


*Fig. 3. The pressure $P_g$ measurements diagram during the glow discharge cleaning in argon atmosphere*

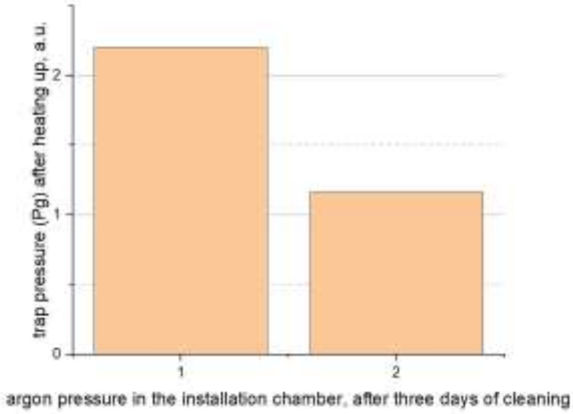


*Fig. 4. $P_g$ pressure measurements carried out during the 2$^{nd}$ and the 5$^{th}$ cleaning days. Argon pressure of 2.57·10$^{-2}$ Torr*

The first three diagram bars are measurement results with different argon pressure. One measurement was done during one day. The diagram bars are aligned in chronological order. Fig. 3 shows that the pressure $P_g$ decreased each next cleaning day.

Fig. 4 shows $P_g$ pressure measurements diagram with 3 days interval. It is clearly seen that controlled pressure $P_g$ decreased almost 2 times. This indicated the success of vacuum chamber cleaning regime.

## CONCLUSIONS

The mass-spectrometer measurement complex was modernized. The complex functionality was demonstrated during joint operation with cryogenic trap during dynamics control of the glow discharge cleaning in argon atmosphere. The next stage of the complex functioning will include installed mass-spectrometer measurements of pumped gases composition.


## ACKNOWLEDGEMENTS

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## МОДЕРНІЗАЦІЯ МАС-СПЕКТРОМЕТРИЧНОГО ДІАГНОСТИЧНОГО КОМПЛЕКСУ З КРІОГЕННОЮ ПАСТКОЮ

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Проведено модернізацію мас-спектрометричного діагностичного комплексу на стелараторі Ураган-2М. Змінено конструкцію вакуумної системи комплексу. Встановлено систему контролю температури поверхні кріогенної пастки та тиску в камері пастки під час її нагрівання. Також встановлено новий мас-спектрометр PRISMA PRO. Проведено перші вимірювання динаміки очищення вакуумної камери стеларатора під час очищення тліючим розрядом в атмосфері аргону.