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VACUUM SYSTEM OF THE NSC KIPT SCA "NEUTRON SOURCE". CURRENT STATUS

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To ensure the required design parameters of the electron beam and the reliable operation of the 100 MeV/100 kW electron accelerato-driver at the NSC KIPT SCA "Neutron Source" research facility as a whole, the accelerator's vacuum system must meet the conditions and criteria for achieving and maintaining an ultra-high vacuum (UHV) that are about $10^{-8}…10^{-9}$ Torr. This publication provides an overview of the linear electron accelerator's vacuum system, its features, characteristics, layout, and conditions for achieving operating residual gas pressure in the accelerator vacuum chamber, as well as the current status and future plans for the vacuum system operation.

INTRODUCTION

The Department of Nuclear and Accelerator Systems at the Kharkiv Institute of Physics and Technology (NSC KIPT) has developed and commissioned a subcritical nuclear assembly (SCA) equipped with a 100 MeV/100 kW linear electron accelerator as a driver (Fig. 1) [1–4]. The SCA is a new type of accelerator-driven system (ADS), since the intensity of the nuclear fission reaction of the ^{235}U isotope in the core is controlled by the intensity of the electron accelerator beam. The main objective of the NSC KIPT nuclear facility project is to create a modern experimental base for conducting research on fast, thermal, and cold neutrons in various fields of fundamental science, as well as for solving a wide range of applied problems.

One of the basic technological system of the facility to provide the stable operation is vacuum system. The article devoted to the short description of the facility vacuum system and its current status.

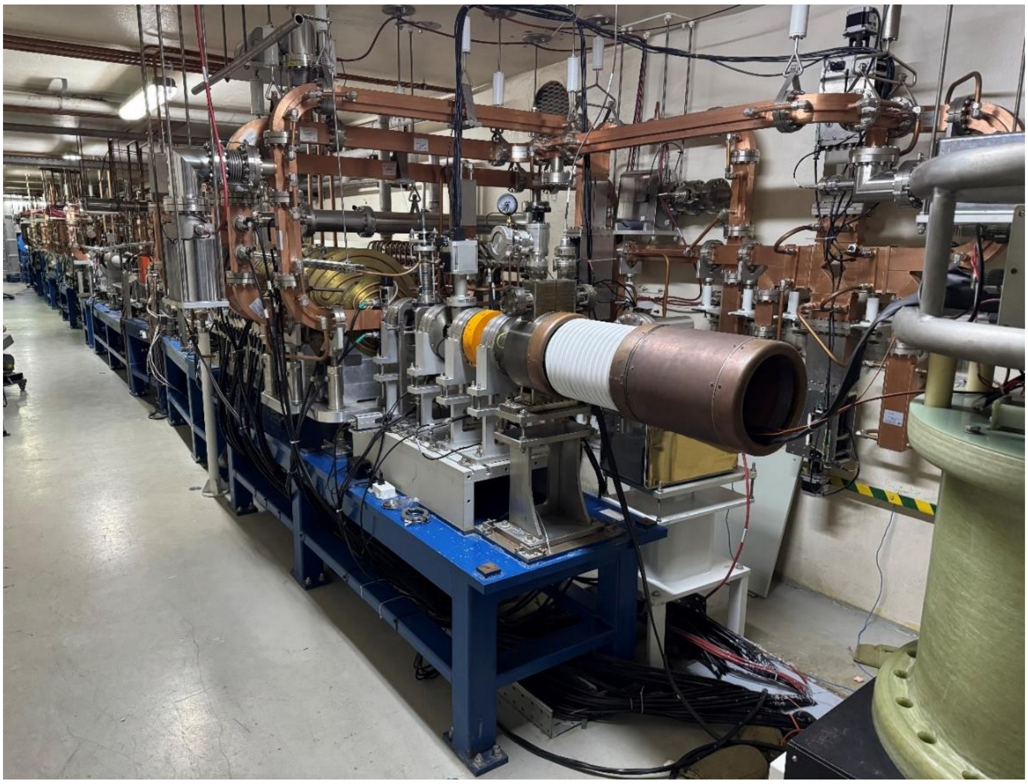

Fig. 1. Electron accelerator SCA

VACUUM SYSTEM LAYOUT

The vacuum system of the NSC KIPT SCA "Neutron source" is oil-free and shuld provide the necessary conditions for the formation of the electron beam and its transportation at the neutron-generating target (NGT) [5] without significant losses [6, 7], as well as ensure the fastest possible restoration of operating residual gas pressure after any vacuum facility failure. The vacuum system is organized into sections and subsections and is divided by vacuum valves with metal shutters. Fig. 2 shows the structure of the neutron source vacuum system. Table shows the structure of the vacuum system.

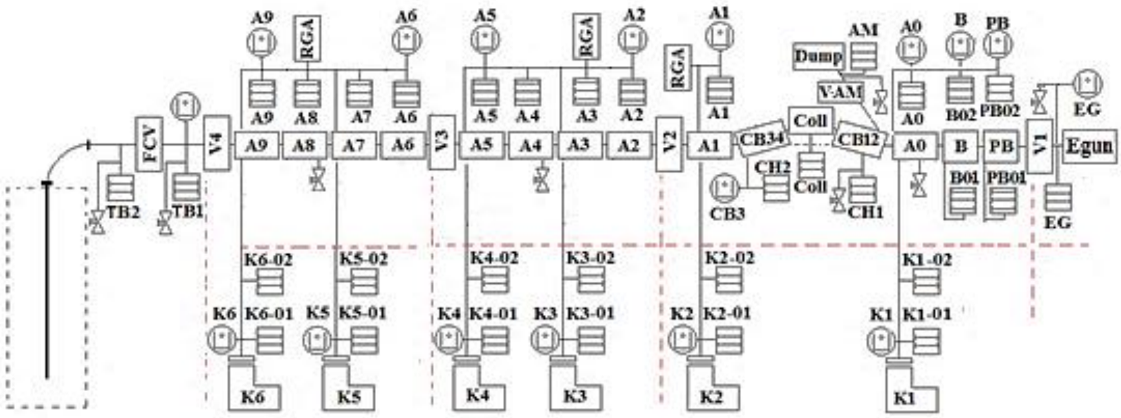

Fig. 2. Layout of the vacuum system of the SCA

NSC KIPT Neutron source SCA facility equipment

Egun	– electron gun		– diode pump
PB B	– pre-buncher and buncher		– triode pump
CB	– electromagnetic chicane		– vacuum measurement probe
Coll	– collimator	V-....	– angular manual probe
A-....	– accelerating sections	FCV	– Fast closing valve
K-....	– klystrons	RGA	– Quadrupole mass spectrometer
	– angular manual valve		– Neutron generating target (NGT) in subcritical assembly
	– special quick flange		

The first section of the linear electron accelerator [8] is the component which is responsible for forming, phasing, and correcting the position of the electron beam for its transportation from the start point, which is accelerator's electron gun. The second and third sections of the accelerator are the sections, where the electron beam is accelerated, focused, and defocused, ensure its transport from the first accelerating section to the accelerator exit. The bending section of the accelerator [9] is the crucial system component, which performs the bending and delivery of the accelerated charged electron beam to the NGT [5]. During the physical start-up, the operation of the accelerator vacuum system, with an average pressure in the accelerator vacuum chamber of $\sim 3.2 \cdot 10^{-9}$Torr, which is at the upper limit of the required average pressure for charged-particle accelerators of this type, was provided and allowed successful start-up of the facility [4].

VACUUM SYSTEM CURRENT STATUS

At present, NSC KIPT SCA "Neutron source" facility is in "Full Shutdown" mode. During the first few months of unstable power supply, work was carried out to maintain vacuum conditions in the sections of the accelerator vacuum chamber, but further all magnetic discharge pumps and measuring instruments were shut down to avoid equipment required stable high voltage power supply failures.

After the long shut-down the average residual gas pressure in the sections of the accelerator vacuum chambers was about $\sim 10^{-1}$Torr.

To provide preliminary oil-free vacuum value of about $\sim 1 \cdot 10^{-7}$Torr and make it possible to activate magnetic discharge pumps mechanical and turbo-molecular pump were used. The value of the residual gas pressure was monitored with cold cathode monitor IKR-050 (Fig. 3) and vacuum monitoring station (Fig. 7).

Fig. 3. Cold cathode monitor IKR-050

Over the course of the year, following the temporary stabilization of the power supply situation, measures were taken to restore vacuum conditions in all parts of the accelerator vacuum chamber.

To reduce the load on the vacuum pumps, each section was evacuated sequentially and separately from the other sections.

As for the electron gun, taking into account the small vacuum volume and good metal sealings, it was able to achieve a good vacuum value quickly.

At the moment, E-gun is under vacuum pumping and keep gun cathode in operation conditions. At 4 kV vacuum pump voltage and pumping current of about 83.9 μA the average residual gas pressure in the E-gun volume is about $\sim 9.6 \cdot 10^{-8}$Torr.

When pumping down the first section of the accelerator, given the complexity of the structure with its numerous devices, transitions, assemblies, and flanges, the process took 4 h. The ion pumps in the second section of the accelerator were gotten to operating mode with a brief preliminary pumping-down lasting approximately 15 min. The magnetic discharge pumps of the third section of the injection channel were gotten to operating mode without preliminary pumping, as the residual vacuum was sufficient.

During the restart of the accelerator vacuum pumping the exchange of the water RF loading of the 7^{th} accelerating section, which is vacuum element, was performed and vacuum sealings were provided (see Fig. 4, 5).

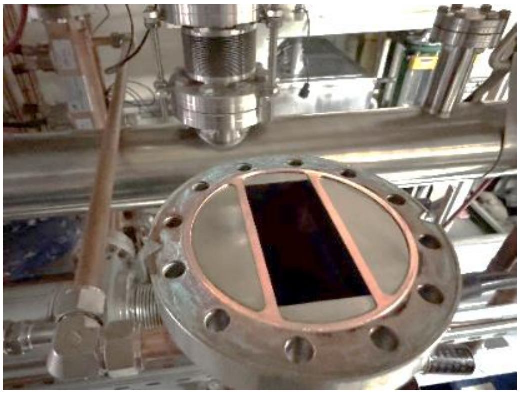

Fig. 4. Landing place for 7^{th} RF water loading

Fig. 5. New installed 7^{th} RF water loading

It proved impossible to perform a preliminary vacuum evacuation of the accelerator bending section in order to subsequently bring the magnetic discharge pumps into operating mode. Presumably, the vacuum seal at one of the joints (Fig. 6) had leakages over such a long period of time, resulting in low level of reference residual gas pressure (of about $\sim 5 \cdot 10^{-5}$Torr). An experimental 5 mm thick lead (Pb) vacuum sealing ring with a metal flange was tested in one of the vacuum system assemblies.

Fig. 6. Lead vacuum sealing

In order to inspect and "tighten" the vacuum sealings, access is required to the vacuum assembly and sealings, which is enclosed within a biological shielding. Given the current situation, it is not possible at this time to open the biological shielding to access the vacuum assembly due to nuclear and radiation safety requirements.

During the physical start-up of the facility, the residual gas pressure in the accelerator's bending part reached a value of $\sim 5.8 \cdot 10^{-9}$Torr and were kept at the same level during a long period of time up to the lost of power supply with two magnetic discharge pumps 150 l/s capacity.

After restart of the vacuum evacuation the accelerator vacuum system showed good performance and possibility to provide operation vacuum conditions for further NSC KIPT SCA "Neutron source" operation without serious repairments. The operation conditions of the working control panel are shown in Fig. 7.

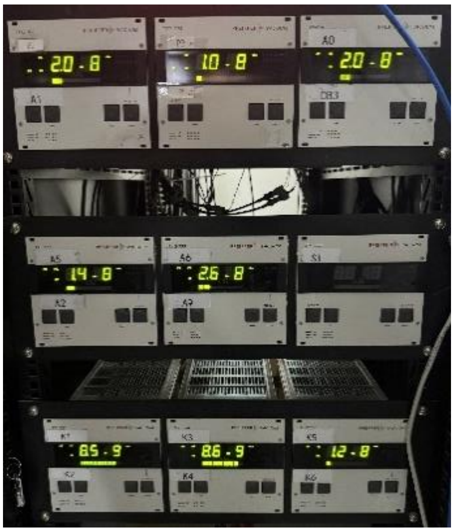

Fig. 7. Vacuum monitor panels

CONCLUSIONS

After restart of the vacuum evacuation the accelerator vacuum system showed good performance and possibility to provide operation vacuum conditions for further NSC KIPT SCA "Neutron source" operation without serious repairments.

REFERENCES

1. A. Zelinsky, O. Bezditko, P. Demchenko, et al. NSC KIPT neutron source on the base of subcritical assembly driven with electron linear accelerator // *Proceedings of IPAC 2013.* 2013, p. 3481-3483.
2. A. Zelinsky, Y. Chi, S. Pei, et al. Design studies on 100 MeV/100 kW electron linac for NSC KIPT neutron source on the base of subcritical assembly driven by linac // *Proceedings of IPAC 11*. 2011, p. 1075-1077, TUPC034.
3. I.M. Karnaukhov, O.P. Bezditko, B.V. Borts, et al. Reactivity measurement methods and the first results of the physical start-up for the nuclear subcritical facility “Neutron Source // *Ukr. J. Phys.* 2023, v. 68, p. 147-161.
4. I.M. Karnaukhov, O.P. Bezditko, B.V. Borts, et al. Research of neutron-physical characteristics of the Subcritical Nuclear Facility “Neutron Source” of NSC KIPT during the physical start-up // *Dopov. Nac. akad. nauk Ukr*. 2024, N 3 (in Ukraine).
5. I.M. Karnaukhov, B. Borts, A. Zelinskiy, et al. A tungsten neutron-generating target of a neutron source based on a subcritical assembly driven with an electron accelerator // *Proc. of IPAC 23*, Venezia, 07 - 12 May 2023, p. 1046 - 1049, DOI: 10.18429 / JACoW-IPAC 2023 - TUPA148.
6. E. Al – Dmour. Fundamentals of Vacuum Physics and Technology// *Proc. of the 2017 CERN Accelerator School course on Vacuum*, p. 1-21.
7. B.D. Ershov et al. *Synchrotron accelerator vacuum systems and accelerator storage complexes.* Revie OA - 49. L.: NIIEFA, 1982, 101 p.
8. A.N. Gordienko, V.G. Grevtsev, I.M. Karna-ukhov, A.O. Mytsykov, A.Yu. Zelinsky. Vacuum system of the NNC KIPT SCA “Neutron source”. The first section of the linear accelerator // *Problems of Atomic Science and Technology*. 2025, №2 (156), p. 159-165.
9. A.N. Gordienko, V.G. Grevtsev, A.O. Mytsykov, A.Yu. Zelinsky. Vacuum system of the NSC KIPT SCA “Neutron source”. Bending part of the Liner accelerator transportation channel // *Problems of Atomic Science and Technology.* 2025, N 6(160).

ВАКУУМНА СИСТЕМА ПКЗ ДЖЕРЕЛО НЕЙТРОНІВ ННЦ ХФТІ. СТАН СПРАВ

О.М. Гордієнко, В.Г. Грєвцев, Ф.А. Пєєв, А.Ю. Зелінський

Для забезпечення необхідних геометричних розмірів електронного пучка та надійної роботи прискорювача електронів 100 МеВ/100 кВт потрібно забезпечити вакуумну систему прискорювача відповідними умовами для отримання та підтримки надвисокого вакууму (UHV). Представлено огляд вакуумної системи лінійного прискорювача електронів, її особливості, характеристики, компонування та умови досягнення робочого тиску, а також результати роботи вакуумної системи при фізичному пуску установки, викладено поточний стан та майбутні плани.