ACHIEVEMENT OF NECESSARY VACUUM CONDITIONS IN THE NICA ACCELERATOR COMPLEX

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Abstract

NICA is the accelerator collider complex under construction at the Joint Institute for Nuclear Research in Dubna. The facility is aimed at providing collider experiments with heavy ions up to Gold in a center of mass energy range from 4 to 11 GeV/u and an average luminosity up to 10^{27} cm^{-2} s^{-1}. The collisions of polarized deuterons are also foreseen. The facility includes two injector chains, a new superconducting booster synchrotron, the existing superconducting synchrotron Nuclotron, and a new superconducting collider consisting of two rings, each of about 500 m in circumference [1].

Vacuum volumes of the accelerator booster and Nuclotron and the superconducting collider are divided into volumes of superconducting elements thermal enclosure and beam chambers. The beam chambers consist regular cold periods, which are at a temperature of 4.2K to 80K, and warm irregular gaps at room temperature. Operating pressure in thermal enclosure vacuum volumes have to maintained in the range of 1×10^{-7} to 1×10^{-4} mbar, in the beam chamber cold and warm areas – not more than 2×10^{-11} mbar. The description of way to achievement and maintenance of the working vacuum in the NICA project are presented.

GAS COMPOSITION OF THE VACUUM VOLUMES

Gas composition in vacuum volumes depending on many factors: choice of material, purity, heating of vacuum system, type of pumps, temperature mode, photon, electron or ion bombardment of the surface, etc.

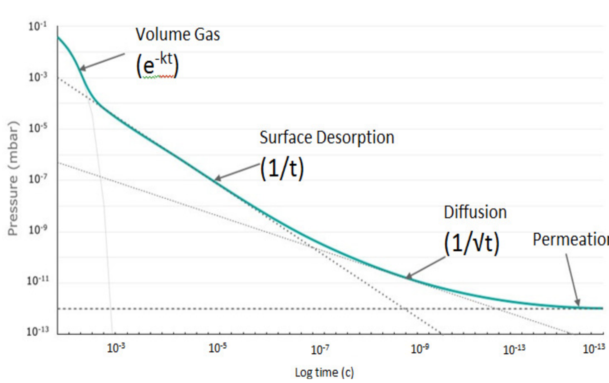

Figure 1 **:** Pump-down diagram.

The main gas constituents of the atmosphere are nitrogen and oxygen. Other gases, such as argon, carbon dioxide and water steam are less than 1% of the total volume of air.

Water is the main component in the unheated metal vacuum chambers. Degassing of water is not significantly dependent on the nature of the metal, surface treatment, and temperature conditions (at temperatures less than 110°C). Currently there are practically no methods other than baking to remove water from the metal surfaces. Diagram of achieving extreme-high vacuum is shown in Figure 1.

Hydrogen is the main residual gas, which is desorbed from the metal surface, when obtaining an ultra-high vacuum. The process of hydrogen degassing depends on the properties of the metal and capacity of the surface at a constant temperature. Heating at a high temperature (up to 900°C) reduces the content of hydrogen on the surface by more than two orders of magnitude [2].

VACUUM VOLUMES OF THE NICA

NICA complex consists of two warm linear injectors, two superconducting synchrotron (Nuclotron and booster), one superconducting collider and warm transport beam channels.

All vacuum volumes can be divided on three different types. The first type is volumes without beam, for example the thermal enclosure vacuum volumes. The second type is the volumes, through which beam passes one time. It is the vacuum chambers of linear accelerators and transport channels between accelerators and areas of experiment. The third type is the volumes, through which beam passes many times. It is the volumes of booster, Nuclotron and collider.

The linear accelerators' volumes of LU-20 and LUTI (Linear accelerator of heavy ions) are required vacuum not worth then 1×10^{-7} mbar. Such value is more determined by resistance to high-voltage breakdown and less by accelerating particles.

The vacuum degree in transport channels depends on adjacent vacuum volumes. For example, the vacuum value for transport channel of the beam transfer from LUTI to booster needs to be not more than 1×10^{-7} mbar from the one side and not less than 1×10^{-11} mbar from the another side. And the channel must have high resistance to residual gas migration from LUTI to booster. For the transfer beam channel from Nuclotron to experimental building is enough roughing vacuum (1×10^{-2} mbar).

Requirements for vacuum in booster, Nuclotron and collider are the highest. At the same time the booster requirements are higher than in collider at the expense of low beam energy – 1×10^{-11} mbar. Vacuum in collider must be better than 1×10^{-10} mbar because of prolonged being of particles inside the vacuum chamber – about one

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hour. The Nuclotron requirements are the lowest – 1×10^{-9} mbar, because beam energy is enough for minimization beam lost residual gas [3].

PUMPING SYSTEMS OF LINEAR ACCELLERATORS AND TRANSFER CHANNELS

The vacuum system of the LUTI is divided into three sections by gate vacuum valves (Figure 2). The vacuum equipment is designed for reaching the working vacuum at a level of 1×10^{-7} mbar.

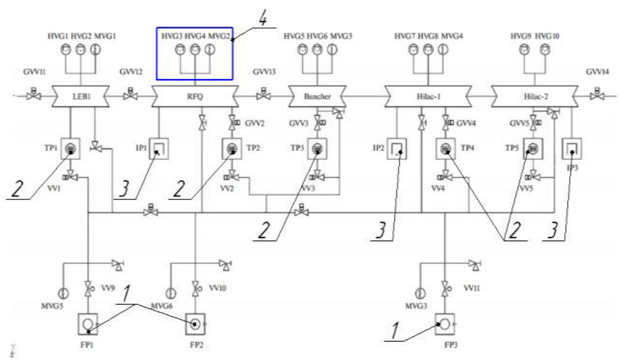

Figure 2: Principle vacuum system scheme of LUTI. 1 – scroll pumps, 2 - turbomolecular pumps, 3 - ion pumps, 4 – cold cathode and Pirani gages.

For reaching working vacuum the turbo-molecular pumps and ion pumps were chosen. For roughing vacuum scroll pumps were used. Cold cathode and Pirani gages were mounted for pressure measure in required range.

Pumping vacuum volumes of LU-20 is realized by two HiPace 2300 (Pfeiffer Vacuum) turbo-pumps (Figure 3).

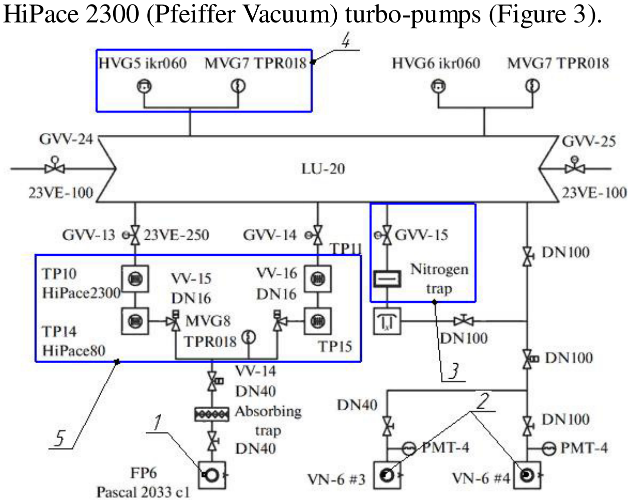

Figure 3: Principle vacuum system scheme of LU-20 injecting complex. 1 – double stage rotary vane pump, 2 - plunger pumps, 3 - diffusion pumps, 4 - cold cathode and Pirani gages, 3 - liquid nitrogen cryogenic pump.

The volume of LU-20 contains mainly water vapor. To pump the water out, a KN-20 000 cryogenic pump cooled by liquid nitrogen was mounted.

Its expected operation rate in the molecular regime is 20 000 L/s, which made it possible to significantly decrease the time of pumping and it takes to reach the working vacuum on the order of 1×10^{-7} mbar.[4]

For pumping beam channels standard scheme with turbopumps are used. Vacuum system of beam transport channel from LU-20 to Nuclotron is shown on Figure 4.

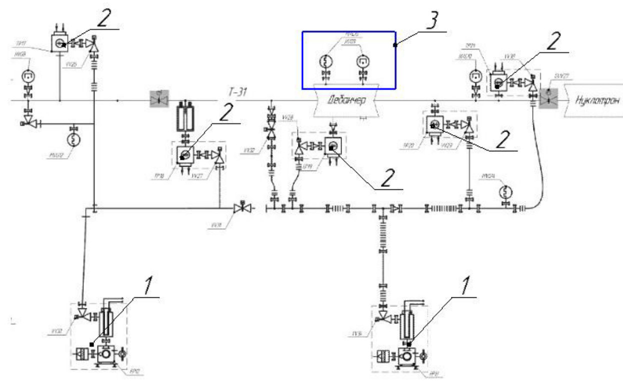

Figure 4: Principle vacuum system scheme of beam transport channel from LU-20 to Nuclotron. 1 – double stage rotary vane pumps, 2 - turbomolecular pumps, 3 - ion pumps, 3 – cold cathode and Pirani gages

PUMPING SYSTEM OF SUPERCONDUCTING BOOSTER SYNCHROTRON

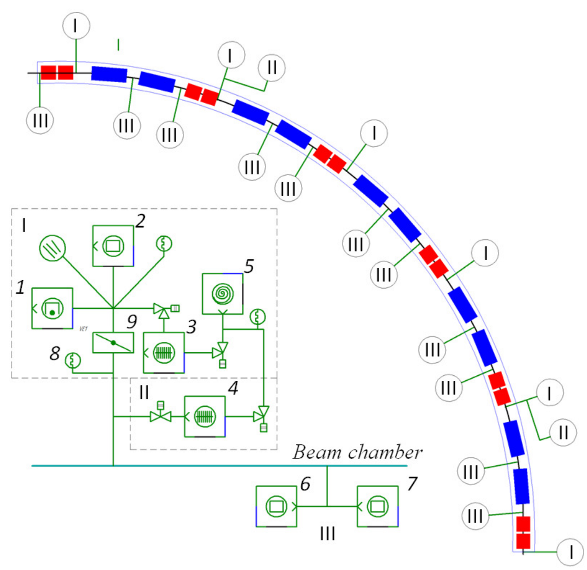

Figure 5: Principle vacuum system scheme of beam chamber`s cold part. I – XHV plant, II - rough evacuation plant, III – chambers with NEG or titan-sublimation pumps, 1 - ion pump, 2 - NEG pump, 3, 4 - turbomolecular pump, 5 - Dry scroll pump, 6,7 - Titan-sublimation or NEG pumps, 8 - UHV and XHV gauges, 9 - all metal gates

The main task for the achievement of working vacuum in the beam chamber will be the hydrogen control. For this goal we will use NEG pumps which are highly recommended in such conditions. For pumping out another gases which cannot be evacuated by NEG, turbomolecular and ion pumps will be situated on vacuum pumping station. Turbomolecular pump will use only for the prepa-

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ration of pumping plant to work. This pump will cut off by all-metal valve (Figures 5, 6).

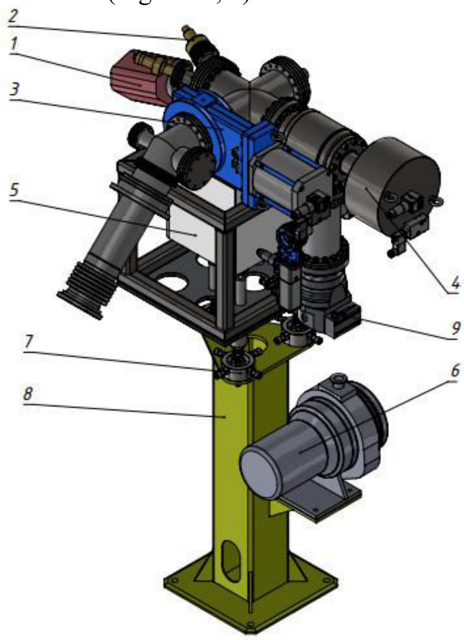

Figure 6: View of XHV station for cold parts. 1- mass-spectrometer, 2 – cold or hot cathode and Pirani vacuum gages, 3 – all-metal gate, 4 – all-metal valve, 5 – ion pump, 6 – scroll pump, 7 - adjustment jack, 8 – upright with frame, 9 – turbomolecular pump

Because of big distance between main pumping stations of cold chamber (around 9 m), in gaps between magnets we will install auxiliary pumps for evacuation hydrogen. Now we are considering three variant of such pumps: 1 – NEG, 2 – titan sublimation pump, 3 – carbon activated adsorption cryopump [5].

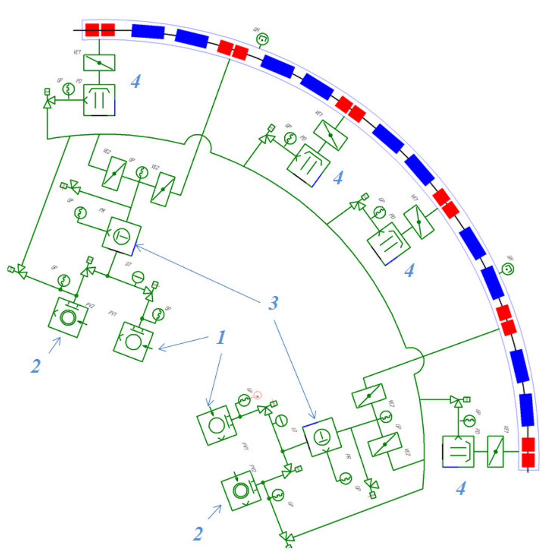

Figure 7: Vacuum system principle scheme of thermal enclosure volume of booster's one quadrant. 1 – single stage rotary vane pumps, 2 - double stage rotary vane pumps, 3 - Roots pumps, 4 - diffusion pump.

The working vacuum of warm gaps will reached by the same set of equipment. There is no problem to warm up and placement of pumps in warm gaps and there is the opportunity to install efficient evacuation systems.

For obtaining the preliminary vacuum in the isolation volume (1×10^{-3} mbar) we want to use tandem with Roots' and rotary-vane pumps. The working vacuum (1×10^{-6} mbar) will reached by diffusion pumps (Figures 7, 8).

This equipment will be working to the reach of helium temperatures in the accelerator in the absence of helium leaks in the isolation volume. After that the pumps will be shut down. The pumping will be continue at the expense of advanced cryosurfaces.

All pumping stations are designed in the form of modules for the purpose of equipment unification and service simplification. Assembly, setup and preparation of modules to work are realizing outside of accelerator ring.

There is the same set of equipment for collider. More detailed configuration of pumping stations will be determinate after the final design of vacuum chamber.

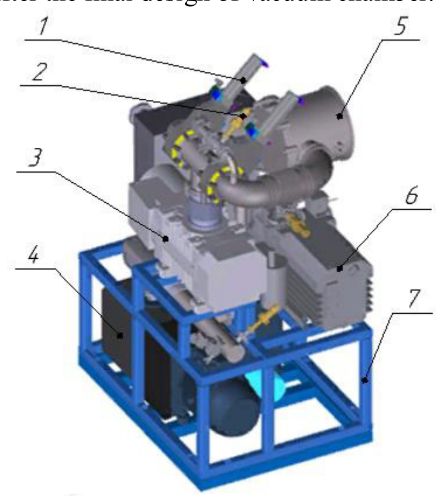

Figure 8: Roughing pumping plant. 1 – vacuum gates, 2 – Pirani gage, 3 – Root's pump, 4 – single stage rotary vane pump, 5 – inlet port DN250, 6 – double stage rotary vane pump, 7 – frame.

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