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VACUUM SYSTEMS FOR THE COOLERS OF THE NICA PROJECT

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Abstract

The NICA accelerator complex contains two electron coolers, one sits at booster and another at NICA collider. They have requirements for the vacuum of 10^{-11} mbar. Despite the coolers have different design the problems of getting vacuum are similar, lack of space along vacuum chambers, presence of the electron beam and oxide cathode usage. The solutions for achieving such a strict requirements are discussed in the article.

INTRODUCTION

The main part of the NICA accelerator complex is the collider for heavy ions up to $^{197}Au^{31+}$, which contains the 2.5MeV cooler. The injection chain of the NICA complex have the gold ions booster. Low energy cooler is one of the elements of the booster that provides sufficient improvement of the ion beam quality. The requirement for vacuum condition is usual for heavy ion accelerators of about 1×10^{-11} mbar [1,2].

VACUUM SYSTEMS

Vacuum system of the high energy cooler consist of two similar parts as shown on Fig. 1. They have identical structure and a little bit different size. Every system may be separated on to three parts by means of gate valves. Main part contains cooling section, which is installed at straight line of the collider so the chamber belongs to the cooler and collider, simultaneously. Other two parts are similar and include part of the transport channel and accelerating (or decelerating) column as shown on Fig. 2.

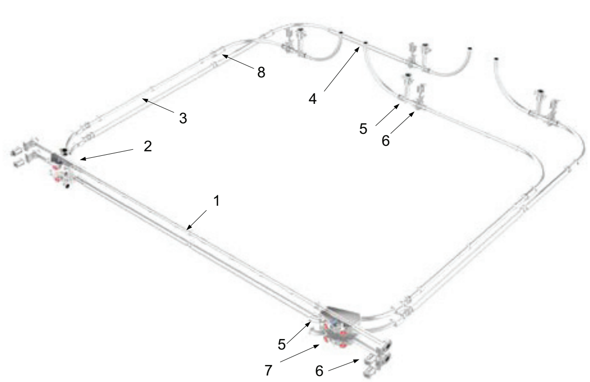

Figure 1: 1 - Cooling section vacuum chamber with BPMs (every one meter), 2 – toroid bend chamber equipped with two 2000 l/s NEG cartridges each, 3 – straight transport channel chamber with BPM, 4 – transition to the electrostatic accelerator, 5 – pumping ports, 6 – gate valves, 7 - NEG cartridges, 8 – special insertion with 1400 l/s NEG cartridge.

VACUUM GENERATION

The vacuum system of the cooler of the NICA booster has similar structure as the main part of vacuum system for the collider despite of the fact that they have completely different size and the shape. As the low energy cooler was successfully commissioned [3] and vacuum condition of 2×10^{-11} mbar was achieved, we rely on all solutions applied for this. Vacuum equipment is similar for both coolers (see Table 1).

Table 1: Vacuum Equipment for One Vacuum System of the High Energy Cooler

Cooling section	Agilent VacIon Plus 300 Noble Diode with TSP Cartridge	2
	CAPACITORR CF 100 MK5 NEG cartridge	4
	Pfeiffer IMR 430, Extractor-system, DN 40 CF-F	1
	VAT All-metal angle valve DN160CF	2
	Turbomolecular pump 700 l/s	1
Transport channels	UHV1400 WAFER MODULE NEG cartridge	1
	VAT All-metal angle valve DN100CF	1
Accelerating column with bending chamber	Agilent VacIon Plus 300 Noble Diode with TSP Cartridge	1
	CAPACITORR D 100 NEG cartridge	4
	Pfeiffer IMR 430, Extractor-system, DN 40 CF-F	1
	Turbomolecular pump 300 l/s	1

Both coolers have oxide cathode as an electron emitter for the electron gun. The oxide cathode, as required, has to be activated during the vacuum system bake-out with back pumping. The activation process is very sensitive to the vacuum condition when the cathode surface is overheated to provide necessary temperature.

Use of the NEG pumps for the distributed pumping was chosen for all vacuum systems belonged to high or low energy coolers. All of those pumps have to be activated at first time of use and reactivated in a definite period according to manual. In a process of reactivation the sufficient amount of hydrogen is released from the pumps surface that have to be pumped with the turbomolecular

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pump. The influence of the hydrogen to the oxide cathode was studied during low energy cooler commissioning [4].

All components of the vacuum system of the low energy cooler were baked out up to 300ºC for about two days with back pumping that provided us required vacuum condition. On the other hand, for the high energy cooler the situation is rather different. According to design, vacuum components of the electrostatic accelerator cannot be backed out. Other parts i.e. cooling section and transport channels are going to be backed up to 250 ºC [5].

ELECTROSTATIC COLUMS

Every electrostatic accelerator of the cooler for collider contains accelerating and decelerating columns equipped with the electron gun and collector correspondently. Schematic view of the columns is shown on Fig.2. One can see that they are very similar to those installed at COSY 2MeV cooler [4]. Main different is the intermediate part as shown on Fig.2. Both columns have four 700 mm long tubes, those provide accelerating or decelerating of the electron beam up to 2.5MeV and down.

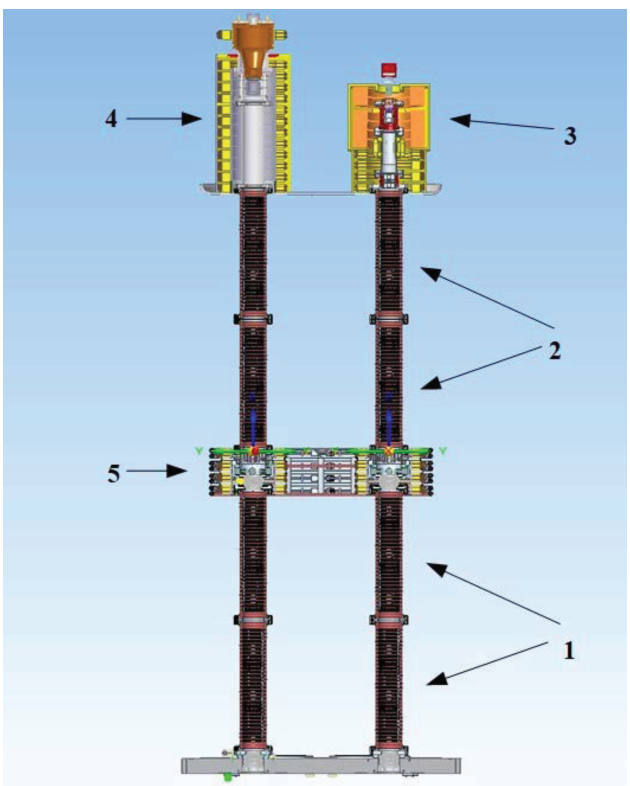

Figure 2: 1 -lower parts of the acceleration tube, 2 - upper parts of the acceleration tube, 3 –gun, 4 – collector, 5 – intermediate plate with mechanical support and NEG pumping chamber including bellows and BPM-s.

Scheme of the intermediate unit of the accelerating column is shown in Fig.3. This part has mechanical support to the column of the high voltage sections so that upper tube has fixed position. Lower tube has a bellows on the top to eliminate possible small misalignment. BPMs are included in to intermediate unit for both accelerating and decelerating columns to measure whether centre of the electron beam is on the right position. Four NEG pumps are installed on the middle of the module to provide distributed pumping.

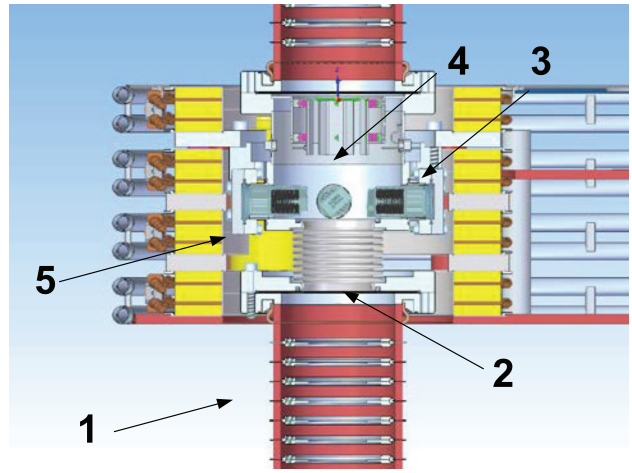

Figure 3: 1 – accelerating tube, 2 – bellows, 3 - mechanical support, 4 - BPMs, 5 - NEG pumps.

ACCELERATING TUBES

Each part of the tube consists of several ceramic and titanium rings brazed togrther as a “sandwich” unless ends where stainless rings are attached (see Fig.2).

Ceramic rings properties:

- outer diameter 135 mm
- wall thickness 7,5 mm
- height 19 mm
- material 94% Al_2O_3, admixture – manganese (pink cesamics)

electrical strength is not less then 10 kV/cm

Accelerating electrodes distributed along the section with the step of 19 mm and have inner diameter of 60 mm. Electrodes on the ends of tube have special shape (see Fig.4) in order to produce more or less homogeneous longitudinal electical field.

Flanges DN160CF are welded on the both sides of the module to connect it to other vacuum parts.

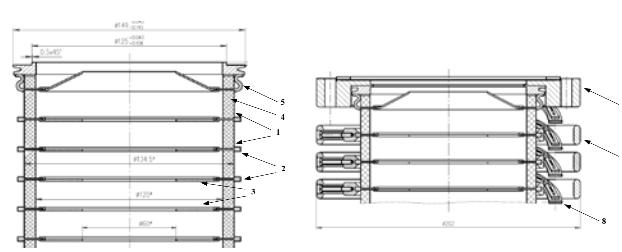

Figure 4: Schematic drawing of the part of the accelerating tube. 1 - ceramics, 2 – titanium rings, 3 – stainless steel electrodes, 4 – ceramic compensator, 5 – stainless steel ending for welding. 6 – flange DN160CF, 8 – divider (chain of HV resistors), 7 – stainless outer rings.

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VACUUM CONDITION ESTIMATION

The vacuum condition estimation was made for the chosen geometry of the accelerating column including tube, gun, collector etc. (see above). Every module was taken as regular structure with total length of 700 mm, pumping speed for both sides is 200 l/s,
thermal desorption for the electrodes surface (room temperature) is 10^{-10} mbar×l/(s×cm^2)

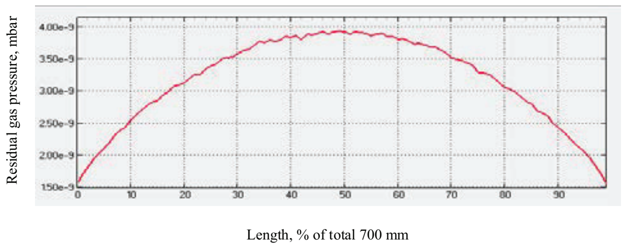

Figure 5: Residual gas pressure depending on accelerating tube length.

Figure 5 shows results of simulations of the residual gas pressure inside accelerating module.
Vacuum conductivity for the accelerating module is calculated as approximately 23 l/s.

The main problems for the required vacuum condition obtaining is the lack of space for the pumping equipment inside high-pressure vessel so it is difficult to increase the pumping speed significantly, besides low conductivity of the tube also limits the ultimate vacuum.

As a result of simulation we should mention that ultimate vacuum inside accelerating tube strongly depends on thermal desorption for the electrodes surface that was taken as 10^{-10} mbar×l/(s×cm^2). This value may vary within 10^{-11} - 10^{-13} mbar×l/(s×cm^2) for the stainless steel annealed in the vacuum oven at 450ºC.

In so far as current design of the electrostatic accelerator doesn't presuppose any backing-out of the vacuum parts inside high pressure vessel in complete assembly the following technique is proposed:

- every vacuum module is backed-out at the special vacuum test bench located as close to the place of assembling as possible.
- after the required vacuum is obtained the module is filled with dry nitrogen (or another appropriate gas)
- module is mounted to the assembly as fast as possible.

SUMMARY

The low energy electron cooler was successfully commissioned at NICA booster. All vacuum techniques were successfully tested during this time.

The high-energy cooler is under construction at BINP. Similar equipment and are applied to it's vacuum system. Nevertheless, the use of other techniques is still possible. So for example, NEG coating of the inner surface of the vacuum chambers is still under consideration.

REFERENCES

[1] I. N. Meshkov and G. V. Trubnikov, "NICA Project: Three Stages and Three Coolers", in *Proc. 11th Workshop on Beam Cooling and Related Topics (COOL'17)*, Bonn, Germany, Sep. 2017, pp. 84-88. doi:10.18429/JACoW-COOL2017-THM21

[2] N.Agapov, A.Butenko, *et al.*, "Booster synchrotron for NICA collider", *Physics of Particles and Nuclei Letters*, 2010, Vol. 7, No. 7, pp. 723–730.

[3] A.Bubley, *et al.*, "Low energy electron cooler for the NICA collider", in *Proc. 11th Workshop on Beam Cooling and Related Topics (COOL'17)*, Bonn, Germany, Sep. 2017, doi:10.18429/JACoW-COOL2017-TUM11

[4] Reva V. B. *et al,* "COSY 2 MeV Cooler: Design, Diagnostic and Commissioning" *in Proc. of IPAC 2014*, Dresden, Germany, May 2014, p. 777-779.