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Jet pump for liquid helium circulation through the fast cycling magnets of Nuclotron

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Plan of presentation

- Description of jet pump
- History of the development
- Jet pumps as the part of cryogenic system of the Nuclotron
- Calculations for jet pumps
- General view of NICA cryogenics
- Conclusions

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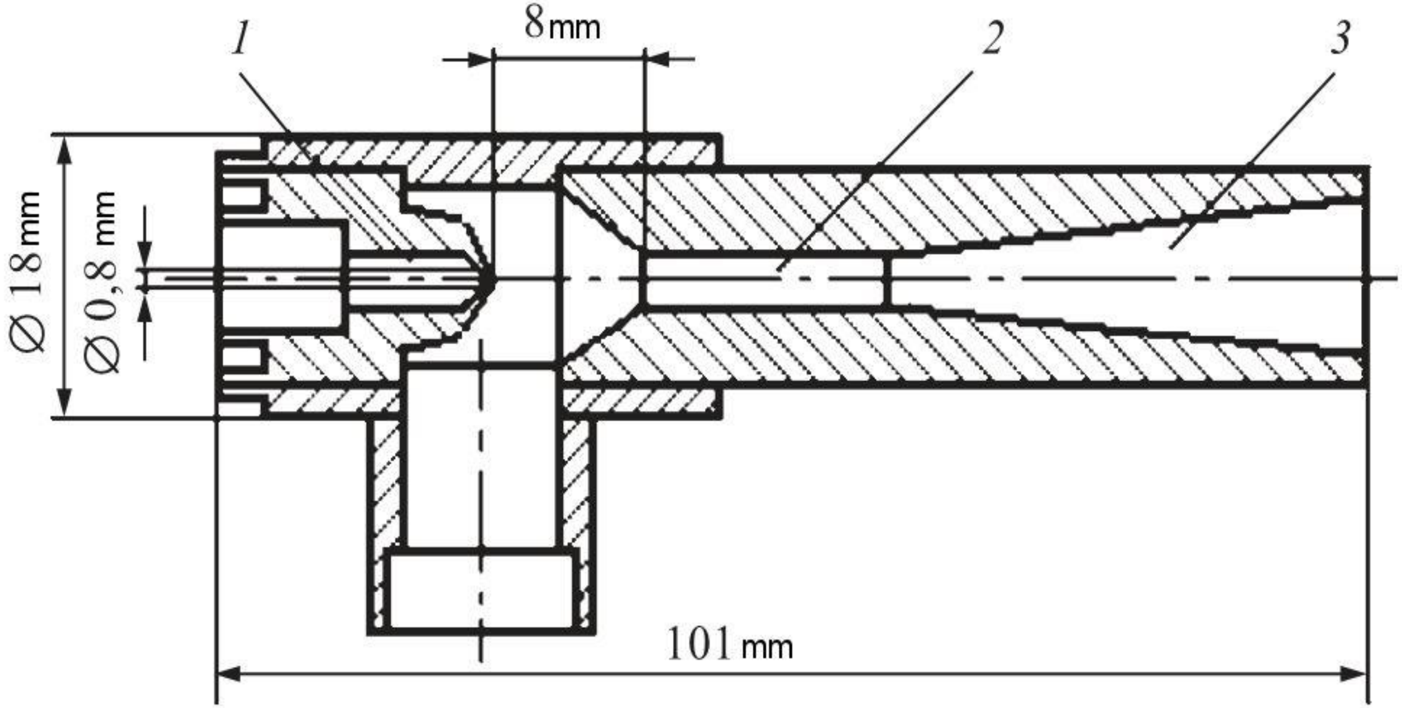

1 – nozzle; 2 - cylindrical mixing chamber; 3 – diffuser

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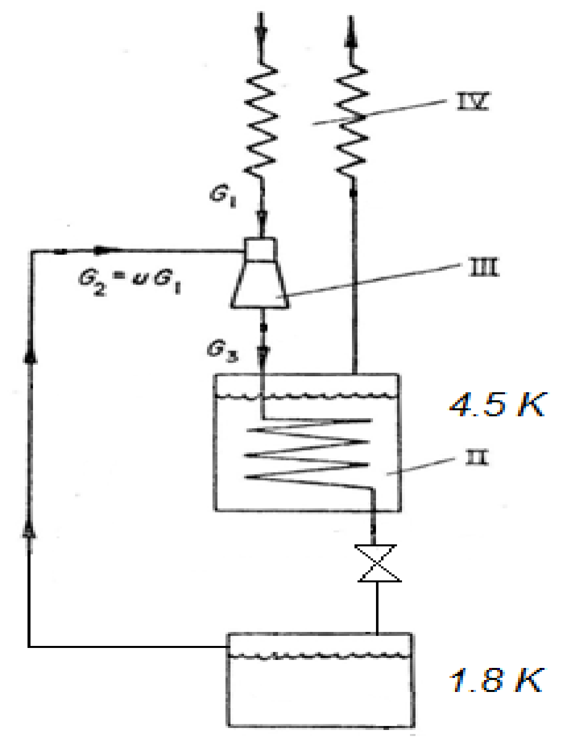
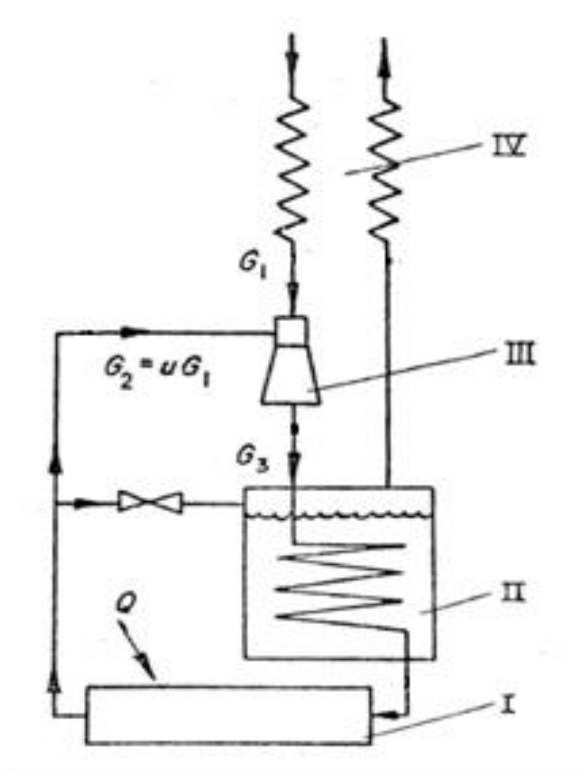
Creation of jet pump to achieve a temperature of 1.8 K by means of pressure decrease in the vessel of liquid helium



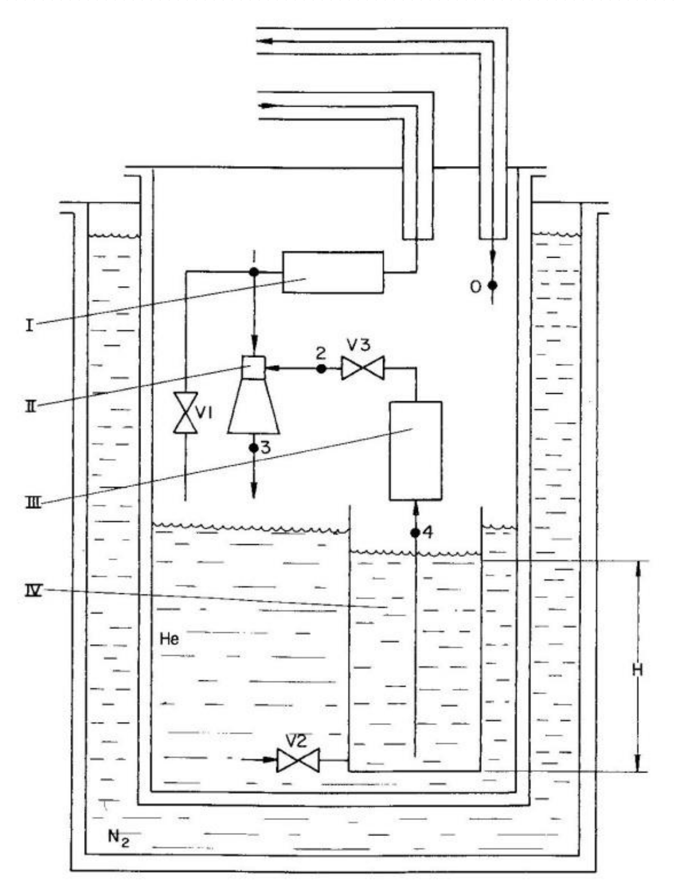
II – liquid helium reservoir, III – jet pump, IV – heat exchanger of the refrigerator

Using a jet pump to circulate a flow of single-phase helium at supercritical pressure for cooling of superconducting devices



I – cooled magnet, II – liquid helium reservoir, III – jet pump, IV – heat exchanger of the refrigerator

Cooling by a two-phase helium



I – filter-adsorber, II – jet pump, III – electric heater, IV – measuring vessel

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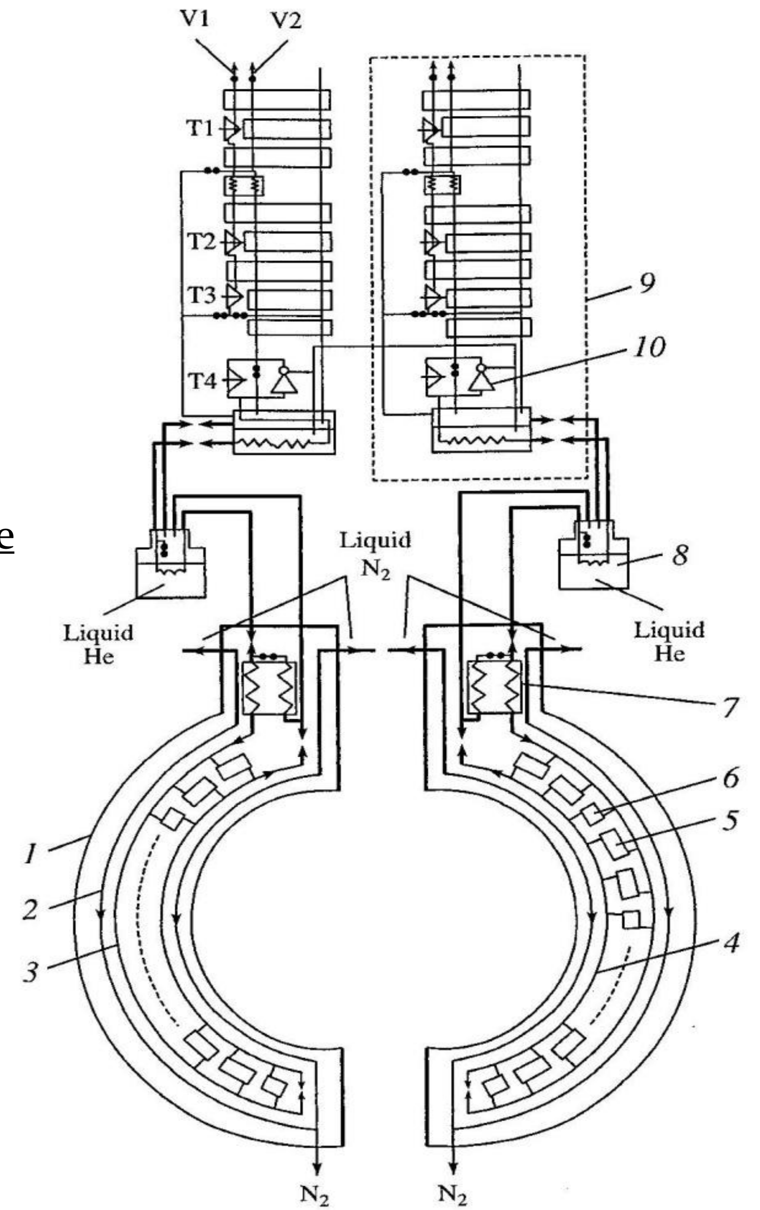
General view of the Nuclotron

Cryogenic system of the Nuclotron

- total capacity of 4000 W at 4.5 K
- pressure at the inlet of refrigerators is 2.5 Mpa
- fast cycling superconducting magnets
- refrigerating by a two-phase helium flow
- very short time for cooldown
- parallel connections of all cooling channels
- “wet” turboexpanders
- screw compressors with a pressure rise of more than 25 in two stages

At least 25% energy efficiency increasing for the whole system by using a jet pumps



1- vacuum jacket; 2 - heat shield; 3 – supply header; 4 – return header; 5 – dipole magnet; 6 – quadrupole magnet; 7 – subcooler; 8 – separator; 9 – refrigeration unit; 10 – jet pump;

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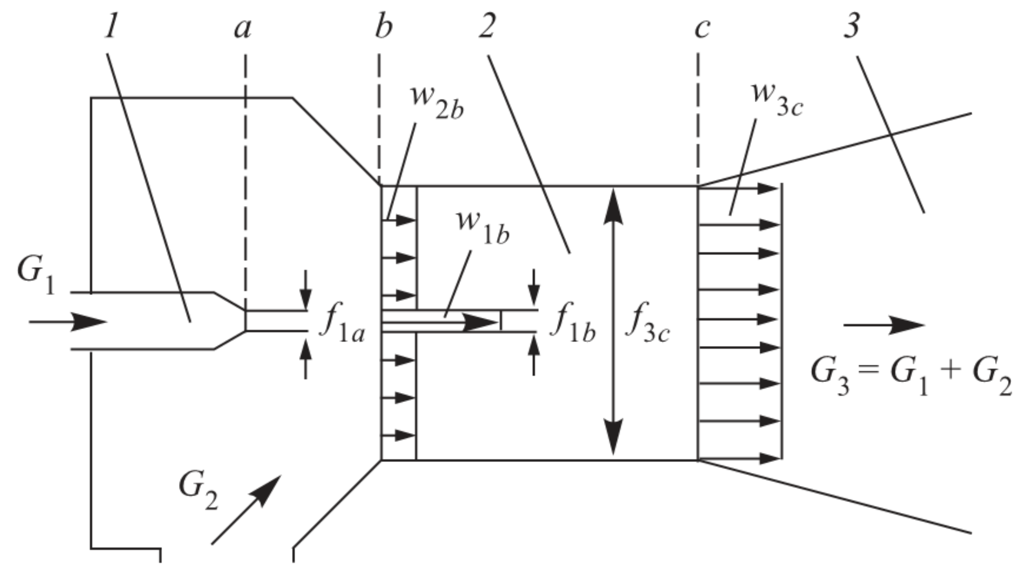
During the device operation, a jet of compressed gas is accelerated in the nozzle, and, in further motion, carries away the injected flow . In the mixing chamber, the speed of the flows are leveled. The mixed flow going out of the mixing chamber is expanded in the diffuser, its speed decreases, and the static pressure of the mixed flow increases up to the pressure of the stagnated flow.



1- the nozzle; 2 – mixing chamber; 3 – the diffuser

The injection coefficient:

$$u = \frac{G_2}{G_1}$$

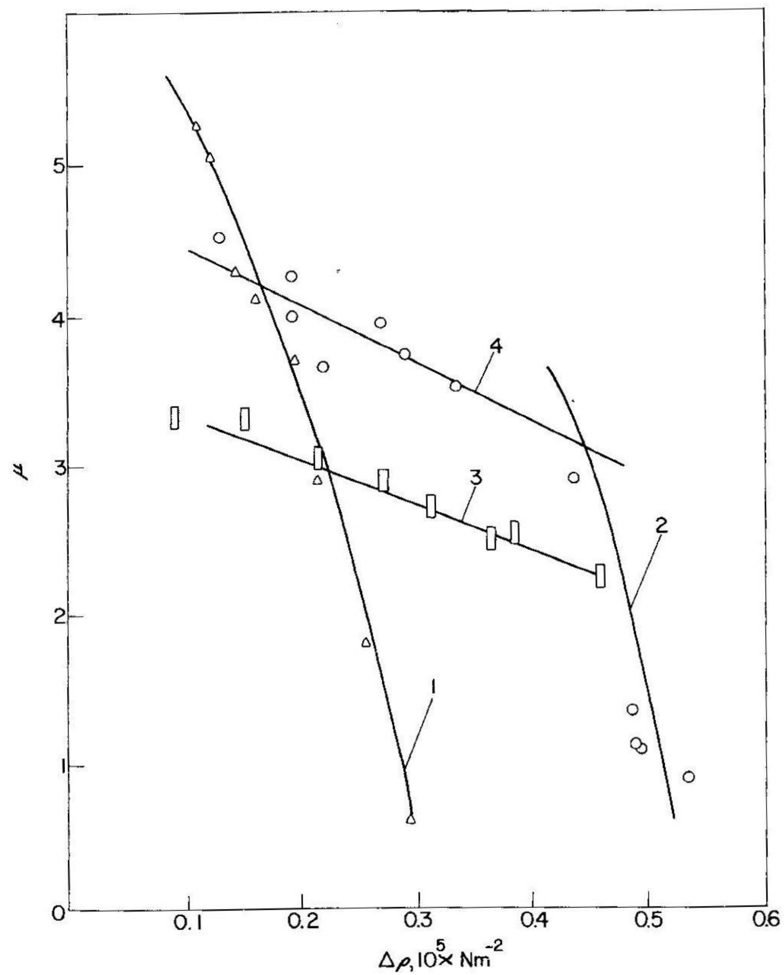
The characteristic equation has a following form:

$$\Delta p = \frac{w_{1a}^2 f_{1a}}{V_{1a} f_{3c}} \left[\varphi_2 + u^2 \frac{f_{1a} V_2}{f_{2b} V_{1a}} \left(\varphi_2 - \frac{0.5}{\varphi_4^2} \right) - (1 + u^2) \frac{f_{1a} V_3}{f_{3c} V_{1a}} (1 - 0.5\varphi_3^2) \right]$$

where Δ Δp – jet pump pressure rise ; p is the pressure; $\varphi_1 = 0.94, \varphi_2 = 0.97, \varphi_3 = 0.90, \varphi_4 = 0.92$ are the speed coefficients of the nozzle. the mixing chamber, the diffuser, and the entrance part of the mixing chamber, respectively ; G is the mass flow; w is the speed; f is the area of the cross section; and V is specific volume.

Comparison of the experimented and calculated characteristics of the jet pump

Despite the discrepancy, we have obtained an important result: the reached values of the mass flow for the injection flow have provided for a more stable operation of the superconducting magnet system of the accelerator, and reduced the power consumption.



1,2- calculation by the momentum equation; 3,4 – limiting modes; μ – injection coefficient, Δp – jet pump pressure rise

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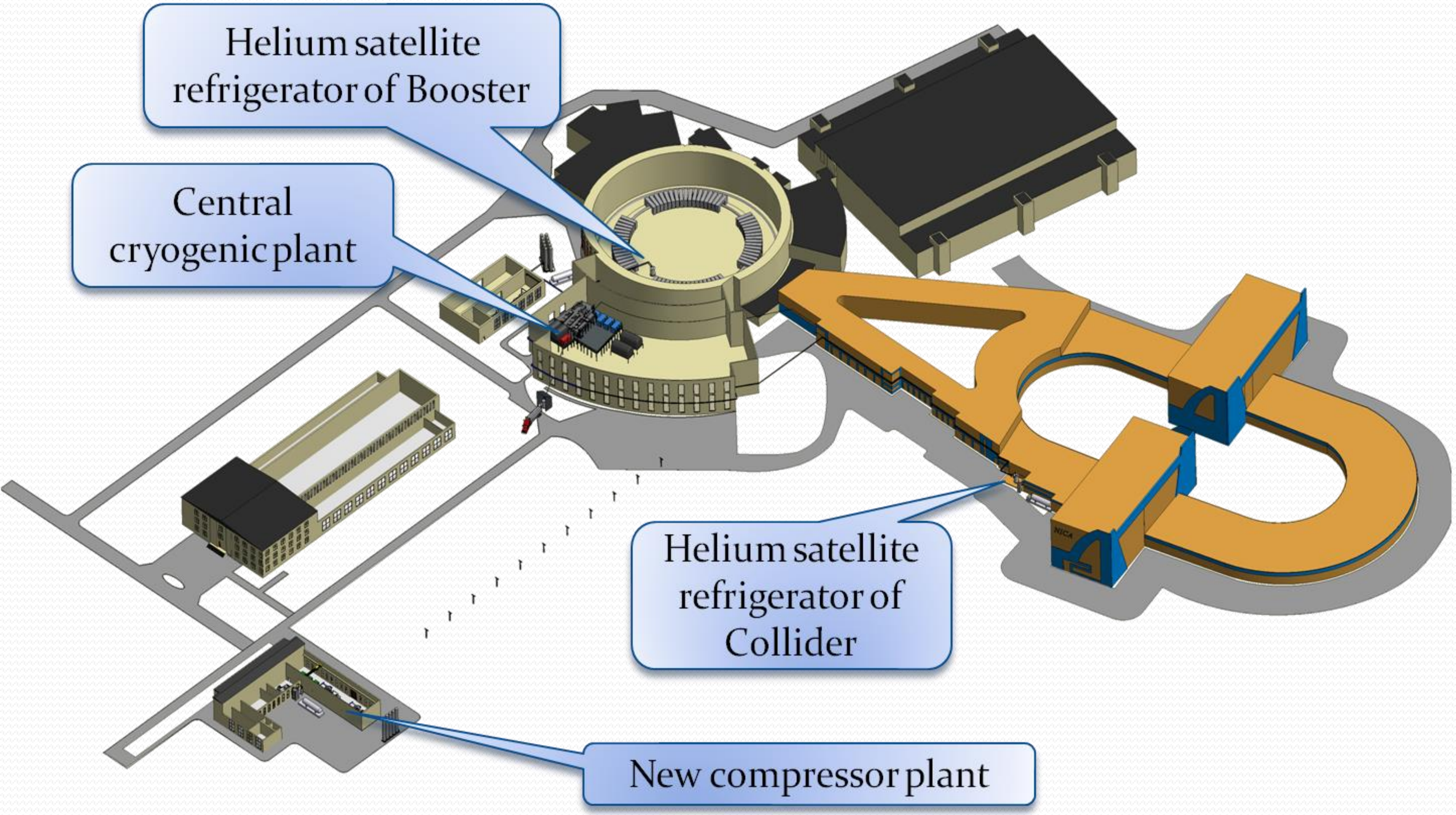
Jet pumps will be a one of the main parts of the cryogenic system of the future accelerators.



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Conclusions

We showed the history of the development of the jet pumps at JINR, theoretical and empirical material we have accumulated over the years of developing and using a jet pumps, and also a results of operating. Moreover, we presented our plans to build a new accelerator NICA complex and to create a cryogenic system for it. The use of jet pumps allowed us to provide a reliable and effective cooling of the Nuclotron and to reduce the energy consumption because with the jet pumps there is no need to turn on the additional compressors like we had to do so in the case with the scheme without the jet pumps.

Thank you for your attention!