Status and Recent Development of the Nitrogen Cryogenic System for the NICA Accelerator Complex at JINR

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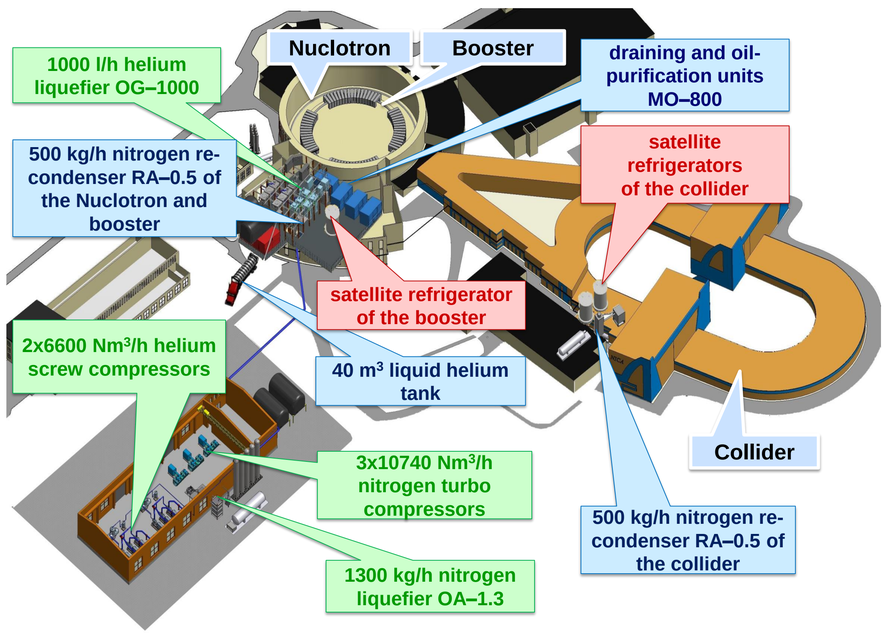
ABSTRACT

The **NICA (N**uclotron-based **I**on **C**ollider f**A**cility**)** accelerator complex is scheduled to be put into operation in full configuration in 2023 at JINR. This facility comprising the existing Nuclotron together with two newly created superconducting accelerators – booster and collider – will require additional refrigerating capacity at 4.5 K and 77 K. The helium cryogenic system of the NICA complex will be constructed as a result of the modernization of the existing equipment for cryogenic supply of the Nuclotron, but **the liquid nitrogen plant will be completely new**. It will be based on a **1300 kg/h nitrogen liquefier** and **two 500 kg/h re-condensers of nitrogen vapors**. This report describes the schematic diagram of the system of liquid nitrogen that will be used for shield refrigerating at 77 K and at the first stage of cooling down three accelerator rings with **the total length of about 1 km and the "cold" mass of 290 tons**. We demonstrate the status and recent development of the nitrogen cryogenic system: location, basic parameters and design of major components and discuss their phased commissioning.

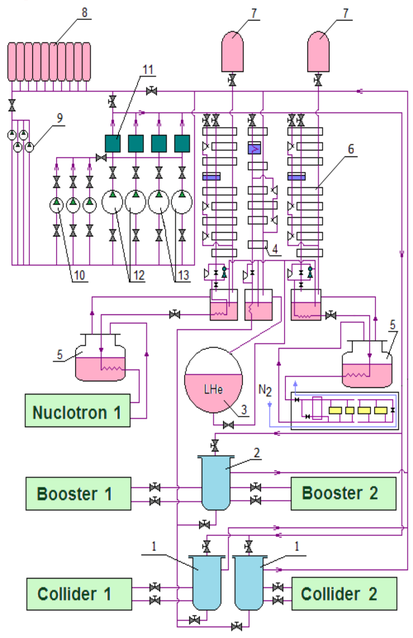
General View of the NICA Cryogenics

The helium cryogenic system of the NICA complex will be constructed as **a result of the modernization of the existing equipment for cryogenic supply of the Nuclotron**.



Main Users of Liquid Nitrogen of the NICA Accelerator Complex

At the designing of the nitrogen cryogenic system not only technical characteristics of **users of liquid nitrogen** of the NICA complex were considered, but also **modes of their operation**.



The flow diagram of the helium cryogenic system for the NICA complex:

1. *“satellite” refrigerators of the collider,*
2. *“satellite” refrigerator of the booster;*
3. *40 m³ liquid helium tank;*
4. *1000 l/h helium liquefier OG–1000;*
5. *liquid helium separators;*
6. *KGU–1600/4.5 helium refrigerators;*
7. *100 m³ gas-holders;*
8. *compressed-helium reservoirs;*
9. *45 Nm³/h piston compressors 1VUV–45/150;*
10. *1200 Nm³/h piston compressors 305NP–20/30;*
11. *draining and oil-purification units MO-800;*
12. *6600 Nm³/h screw compressor “Kaskad–110/30”;*
13. *5040 Nm³/h screw compressors “Kaskad–80/25”.*

Basic parameters of the helium cryogenic system for the NICA complex

Operating temperature, *[K]*	**4.5**
Refrigerating capacity at 4.5 K, *[W]*	**8000**
Total capacity of the compressors, *[Nm³/h]*	**30420**
Total power of electric motors, *[kW]*	**7400**
Flow rate of cooling water, *[m³/h]*	**400**
Total «cold» mass, *[t]*	**290**

The main users of liquid nitrogen of the NICA accelerator complex:

1. Helium refrigerators KGU– 600/4.5 (Nuclotron);
2. Helium liquefier OG–1000;
3. “Satellite” refrigerators (booster and collider);

} T_{nv}≈300 K

4. Thermally insulating shields of the cryostats of the Nuclotron, booster and collider — T_{nv}≈80 K

Modes of operation of the NICA nitrogen cryogenic system:

1. Cool-down mode — **4.5 K<T_{ms}<300 K**
2. Operating mode — **T_{ms}≈4.5 K**

T_{nv} – temperature of the nitrogen vapors, T_{ms} – temperature of the magnet system

Operating Mode of the NICA Cryogenic System

When magnetic systems of all accelerators of the NICA complex are at liquid helium temperature (4.5 K), **consumption of liquid nitrogen will be equal to 1640 kg/h**, including:

<u>for cooling nitrogen shields of the cryostat:</u>

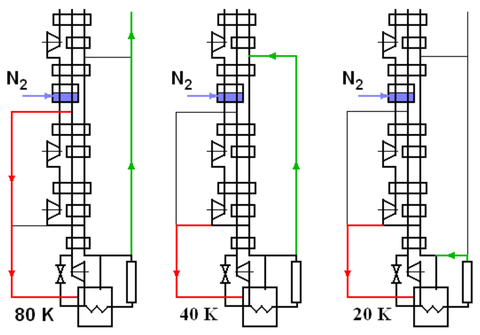
of the Nuclotron	250 kg/h;	**RA–0.5**
of the booster	200 kg/h;	
of the collider	300 kg/h;	**RA–0.5**

<u>consumption in the operating mode:</u>

on the two refrigerators KGU–1600/4.5	330 kg/h;	**OA–1.3**
on the helium liquefier OG–1000	560 kg/h	

To provide the required capacity of the nitrogen cryogenic system of the NICA complex **a liquefier with the capacity of 1300 kg/h (OA–1.3)** and **two re-condensers with the capacity of 500 kg/h (RA–0.5)** will be put into operation.

Cool-down Period of the Nuclotron



The cool-down scheme of the Nuclotron

The Nuclotron:

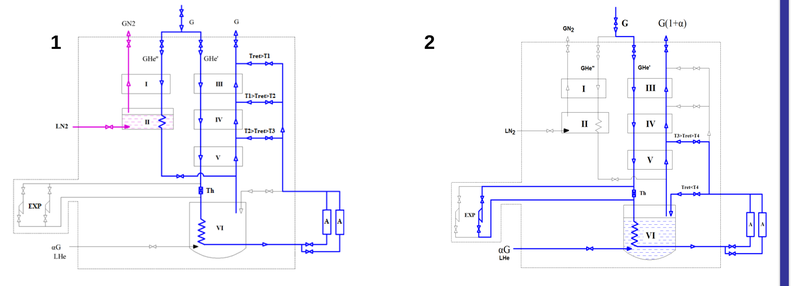
“Cold” mass: M=80 tons

Cool-down time: t=100 hours

LN_2 consumption: G=1000 kg/h

At **the cool-down period of the Nuclotron** the **1300 kg/h liquefier OA–1.3** will compensate the consumption of liquid nitrogen.

Cool-down Period of the Booster and the Collider



The cool-down scheme of the booster and collider*: 1. the first stage, 2. the second stage*

The booster:

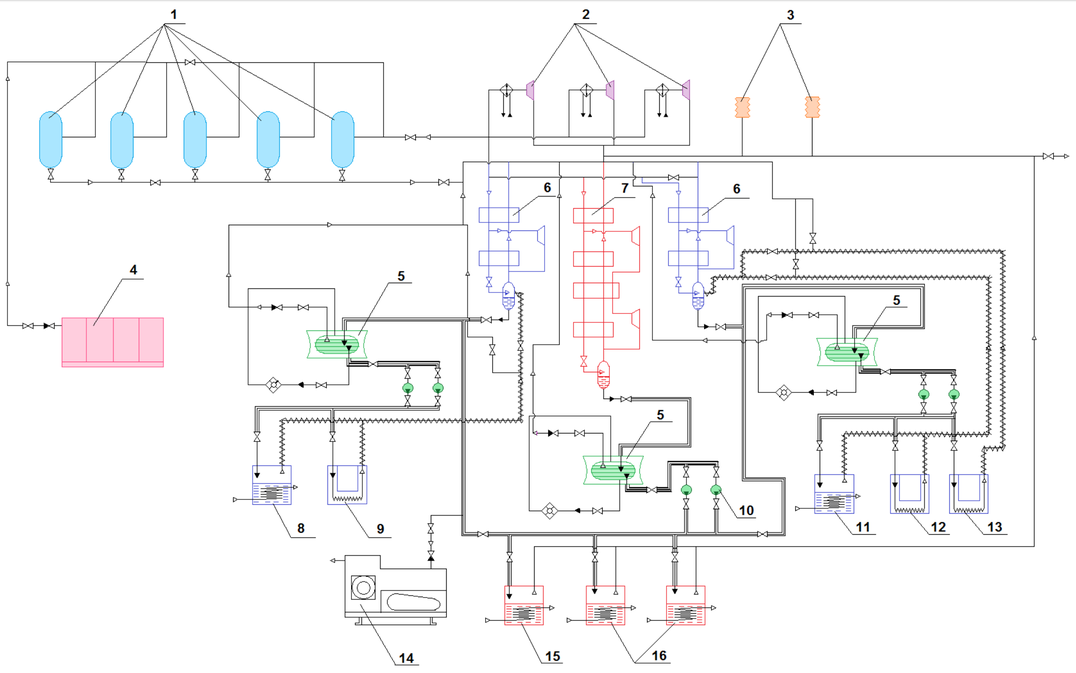
“Cold” mass: M=46 tons

Cool-down time: t=76 hours

LN_2 Consumption: G=500 kg/h

At **the cool-down period of the booster and collider** the corresponding **500 kg/h re-condenser RA–0.5** will compensate the consumption of liquid nitrogen.

Flow Diagram and Phased Commissioning of the NICA Nitrogen Cryogenic System



Flow diagram of the NICA nitrogen cryogenic system:

1. *five 20 m³ compressed nitrogen reservoirs;*
2. *three turbo compressors;*
3. *two 200 m³ gas-holders;*
4. *adsorption nitrogen plant;*
5. *three 30 m³ liquid nitrogen tanks;*
6. *two 500 kg/h nitrogen re-condensers RA–0.5;*
7. *1300 kg/h nitrogen liquefier OA–1.3;*
8. *vats of liquid nitrogen of the “satellite” helium refrigerators for the collider;*
9. *nitrogen shield of the collider cryostat;*
10. *six liquid nitrogen pumps;*
11. *vat of liquid nitrogen of the “satellite” helium refrigerator for the booster;*
12. *nitrogen shield of the booster cryostat;*
13. *nitrogen shield of the Nuclotron cryostat;*
14. *vacuum pump;*
15. *vat of liquid nitrogen of the helium liquefier OG–1000;*
16. *vats of liquid nitrogen of the helium refrigerators KGU–1600/4.5.*

1. The first stage of construction of the LN_2 plant:

Users of liquid nitrogen: 1. two refrigerators KGU–1600/4.5, 2. thermally insulating shields of the cryostat of the Nuclotron;

Equipment: 1300 kg/h nitrogen liquefier OA–1.3, 10740 nm³/h turbo compressor of gaseous nitrogen, five 20 m³ compressed-gas reservoirs, two 200 m³ soft gas-holders, 30 m³ liquid nitrogen tank and connecting cryogenic pipelines.

2. The second stage of construction of the LN_2 plant:

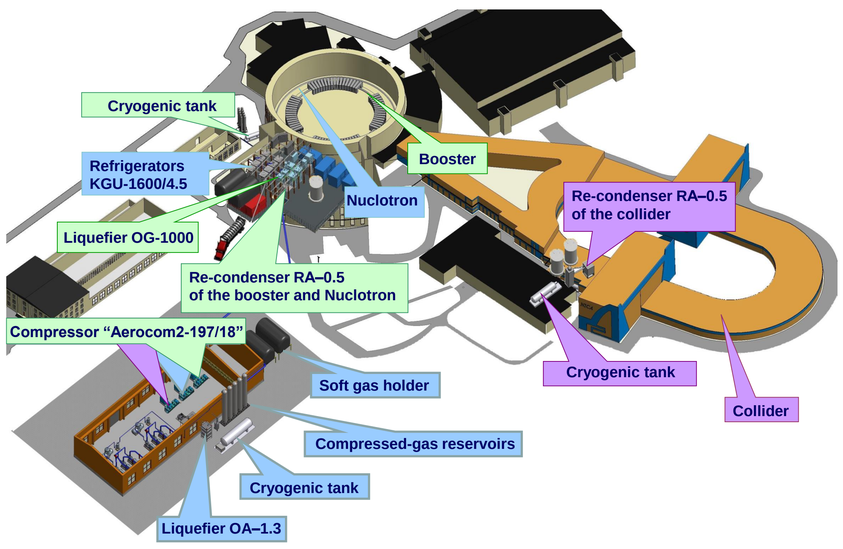
Users of liquid nitrogen: 1. helium liquefier OG–1000, 2. thermally insulating shields of the cryostat of the booster, 3. “satellite” refrigerator of the booster;

Equipment: 500 kg/h nitrogen re-condenser RA–0.5, 10740 nm³/h turbo compressor of gaseous nitrogen, 30 m³ liquid nitrogen tank, connecting cryogenic pipelines, an adsorption nitrogen plant.

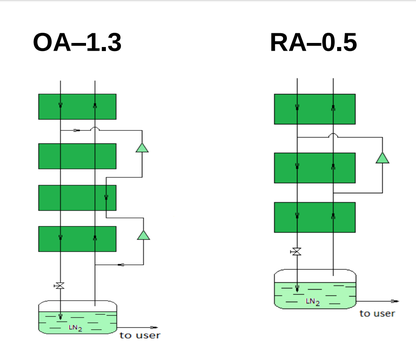
3. The third stage of construction of the LN_2 plant:

Users of liquid nitrogen: 1. thermally insulating shields of the cryostat of the collider, 2. “satellite” refrigerators of the collider;

Equipment: 500 kg/h nitrogen re-condenser RA–0.5, 10740 nm³/h turbo compressor of gaseous nitrogen 30 m³ liquid nitrogen tank and connecting cryogenic pipelines.



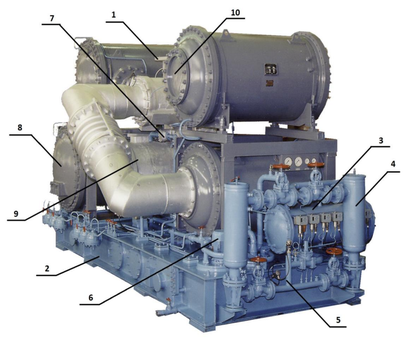
Liquefier OA–1.3 and Re-condenser RA–0.5



The **nitrogen liquefier OA–1.3** and the two **re-condensers RA–0.5** were specially designed by the **Joint-Stock Company NPO GELIYMASH”, Moscow,** to meet the needs of the NICA complex.

Parameter	Re-condenser RA–0.5	Liquefier OA–1.3
Capacity at re-condensation, at least, *[kg/h]*	**500**	**—**
Capacity at liquefaction from 300 K, *[kg/h]*	**350**	**1300**
Operating pressure, *[MPa]*	**1.7**	**1.7**
Power consumption (no more), *[kW]*	**560**	**1600**

The compressor aggregate “Aerocom2–179/18”



The **nitrogen compressor “Aerocom2–179/18”** was specially designed by **the JSC “NII Turbocompressor”, Kazan**, for the NICA complex:

1. compressor housing; 2. frame-oil tank; 3. oil cooler; 4. oil filter; 5. reducing valve; 6. start-up oil pump; 7. basic oil pump; 8. gas cooler; 9. suction line of gas; 10. discharge line of gas.

Parameter	Aerocom2–179/18
Capacity of compressor, *[Nm³/h]*	**10740**
Inlet pressure, *[MPa]*	**0.102**
Outlet pressure, *[MPa]*	**1.8**
Temperature of cooling water, *[° C]*	**20**
Installed power of electric motor, *[kW]*	**1800**