COMMISIONING OF FACILITY FOR ASSEMBLING AND TESTS OF SUPERCONDUCTING MAGNETS

S. Kostromin*, V. Borisov, O. Golubitsky, A. Donyagin, A. Galimov, S. Korovkin, H. Khodzhibagiyan, A. Kudashkin, G. Kuznetsov, D. Nikiforov, T. Serochkina, A. Shemchuk, A. Starikov, A. Tikhomirov, JINR, Dubna, Russia

Abstract

The NICA accelerator complex will include two superconducting (SC) fast cycling synchrotrons (0.6 GeV/u, 211 m circumference booster synchrotron, existing synchrotron Nuclotron of 4.5 GeV/u, 251m circumference) and SC collider of 4.5 GeV/u, 503m circumference having two rings one upon another. Structural magnets of these facilities are SC magnets of Nuclotron-type.

Facility for the assembly and tests of such magnets is under commissioning at the Laboratory of High Energy Physics now. Equipment of the facility for 6 tests benches allocated in separate building of 2600 m^2. Three helium satellite refrigerators with each capacity of 100 W were commissioned. 2 of 6 test benches for magnets testing are assembled and commissioned. NICA booster magnets fist cryogenic tests are done.

INTRODUCTION

The Nuclotron-type design [1] based on a window frame iron yoke and a saddle-shaped SC winding has been chosen for the NICA booster and collider magnetic system [2] (Figure 1) as well as for the SIS100 synchrotron (FAIR project) [3]. Nuclotron-type magnets include a cold (4.5K) iron yoke and a winding made of a hollow NbTi composite SC cable cooled with a two-phase helium flow.

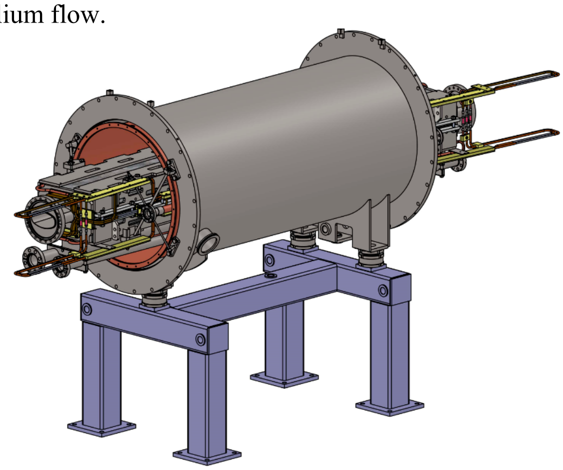

Figure 1: 3D-view of Nuclotron-type dipole magnet module for NICA booster.

The prototype magnets for the NICA booster and collider have successfully passed cryogenic test on the bench [4]. Pre-serial dipole magnets for the NICA booster were tested. These tests include measurements of the magnetic field quality. Start of serial tests of booster magnets are scheduled second half of 2016. Serial production of magnets for the NICA collider is scheduled for 2017 [5]. 3 of 6 benches at the testing facility planned to be available for the testing of the SIS100 quadrupole units [6].

The facility is designed for round-the-clock operation. Following numbers of SC magnets will be assembled and tested: - 40 dipole magnets for the NICA booster;
- 48 quadrupole magnets with multipole correctors for the NICA booster;
- 169 quadrupole magnets with multipole correctors for the SIS100 synchrotron (FAIR project);
- 80 dipole magnets for the NICA collider;
- 86 quadrupole magnets with multipole correctors for the NICA collider;
- 20 final focus magnets.

Using 4 benches one need about 1 year to test all magnets for the NICA booster at an average of 8 tests of magnets per month, of which only 2 or 3 magnets require retests.

Operating simultaneously on 3 benches, one need about 42 months to test all 169 quadrupole units for SIS100. Operating in parallel on the next 3 benches we need about 3,5 years to test all 186 magnets for the NICA collider with an average rate of testing of 6 or 7 magnets per month, of which only 2 magnets will require retests.

DESCRIPTION OF THE FACILITY

Figure 2: Schematic 3d-view of the facility halls and main equipment placement: 1 – Nuclotron-type SC cable production hall; 2 – magnets windings production hall; 3 –assembling the yoke of the magnet and winding, welding and brazing cooling channels of magnets; 4 –room temperature magnetic measurements; 5 –check vacuum tightness of cooling channels, beam pipes and cryostats; 6 –assembling magnets in cryostats; 7 –cryogenic tests of magnets at 6 benches; 8 –power converters hall.

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The location of the equipment at the test facility is shown in Figure 2. The equipment for cable production (see Figure 3) allows producing a Nuclotron-type hollow composite SC cable with the capacity of up to 30 m/h. The diameter of the cooling channel of the cable can vary from 3 to 5 mm. The number of SC wires in the cable may be up to 32. The wire diameter may be up to 1 mm.

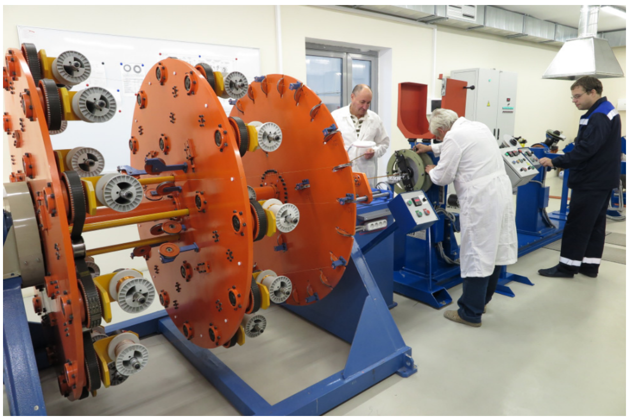

Figure 3: Production of the SC-cable with 18 wires of 0.78 mm diameter for NICA booster dipole magnet.

Hall for manufacturing of SC coils is equipped with a rotating table and tooling for winding of various types of SC coils as well as a furnace for heat treatment of coils with the length up to 3.5 m. Another oven for SIS100 magnets' coils of 6.5 m long already installed and commissioned at the facility.

The hall for "warm" (room temperature) magnetic measurements is equipped with rotating coil measurement systems (see Figure 4-7), pulsed linear regulated power converter with the current up to 100 A [7] and DAQ based on National Instruments PXI measuring electronics and LabVIEW software.

Detailed description of the magnetic measurements technique is presented in [8], [9]. First "warm" magnetic measurements of the booster quadrupole magnets is going at the present moment using dedicated rotating coil probe which allow to measure the parameters of assembled in doublets quadrupole lenses.

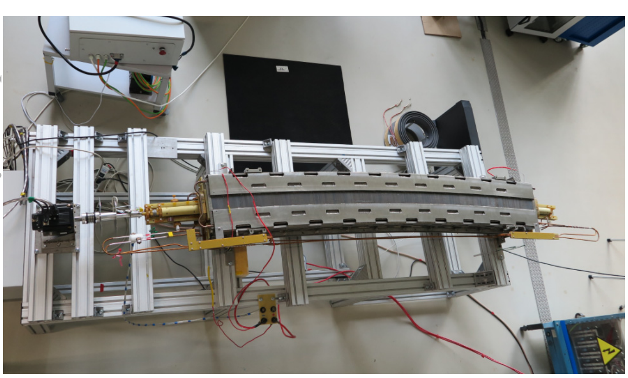

Figure 4: Rotating coils magnetic measurements system for NICA booster curved dipoles.

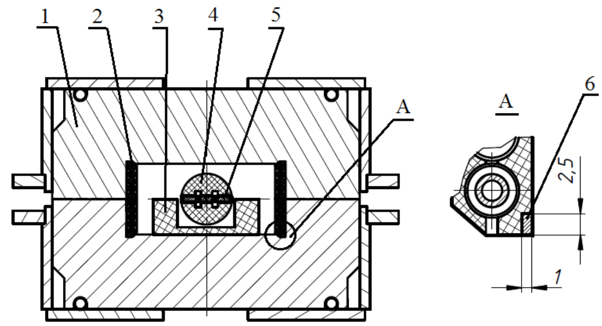

Figure 5: Cross-section of booster dipole with measurements probe inside: 1 – iron yoke, 2 – coil, 3- probe support, 4 – probe rotating part, 5 – rotating coils, 6 – reference coil.

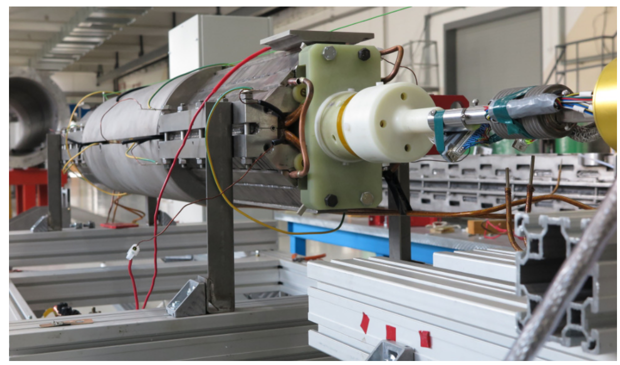

Figure 6: Rotating coils measurements system for NICA booster quadrupole doublets.

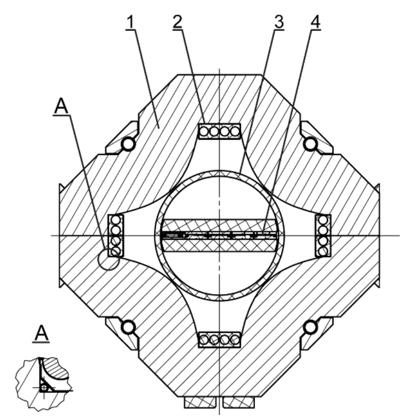

Figure 7: Cross-section of booster quadrupole magnet with measurements probe inside: 1 – iron yoke, 2 – coil, 3- probe coils rotating support, 4 – rotating coils.

Hall for cryogenic tests of the magnets with 3 helium satellite refrigerators (HSR) [10] (see Figure 8), will be equipped with 6 feed boxes with 12 HTS current leads [10] on 18 kA pulse operation, a system for «cold» (at temperature of the liquid helium) magnetic measurements, vacuum and control systems. It is intended to provide cold tests of SC magnets simultaneously at 6 benches and is planned to be used for testing of NICA (booster, collider) and FAIR (SIS100 synchrotron) SC magnets. For the moment three HSR (ILK, Dresden) commissioned, fully tested and ready for operation.

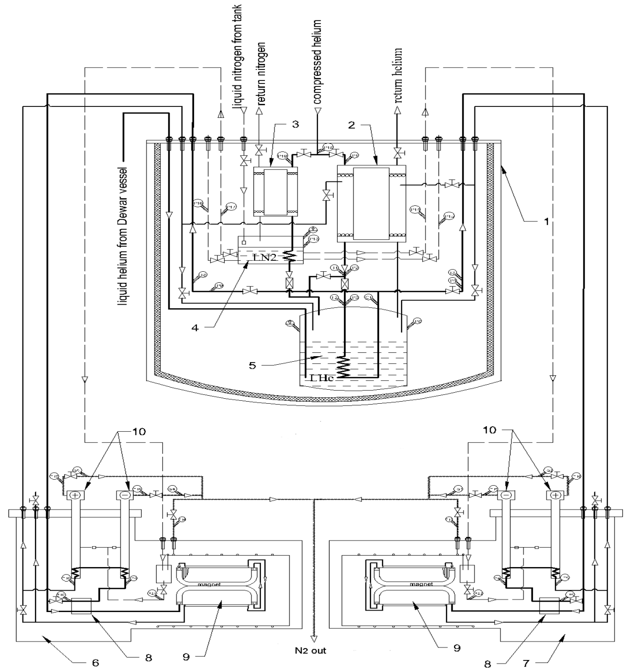

Figure 8: Flow diagram of two test benches: 1 - vacuum shell of the satellite helium refrigerator; 2 and 3 – main and starting heat exchangers; 4 – bath with liquid nitrogen, 5 – bath with liquid helium, 6 and 7 – left and right feed boxes; 8 – sub-cooler of liquid helium flow; 9 – SC magnet; 10 – HTS current leads.

Each of three HSR provides two test benches with liquid helium alternately. Precooling the magnet is carried by compressed helium cooled in bath with liquid nitrogen. High pressure (up to 25 bars) helium flow reduces the time required for cooling the magnet from room temperature to 80 K. The level of liquid helium in the bath is maintained by its transfer from a Dewar with the capacity of 1000 litres. Nominal capacity of the refrigerator is 100 W. Liquid nitrogen is used for cooling heat shields, as well for cooling HTS current leads. Each test bench is provided with the equipment necessary to conduct training SC magnets, measuring energy loss and pressure drop in the magnet when operating in pulsed mode and "cold" magnetic measurements.

MEASURED PARAMETERS OF BOOSTER DIPOLE MAGNET

Harmonics of the magnetic field (in relative units) for pre serial booster dipole are presented in Figure 9. One can see that sextupole component (b3) of the magnetic field is growing up with the main field (or feed current) value. It equals $8*10^{-4}*b1$ at the maximum operating field 1.8 T. This value fit the technical specification for the magnet basing of the analysis of accelerator beam dynamics.

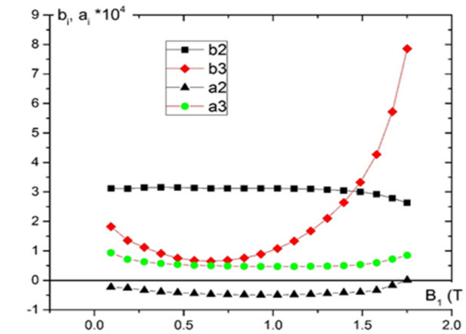

Figure 9: Normal and skew relative harmonics of the FoS booster dipole.

CONCLUSIONS

Facility for the assembly and tests of SC magnets for NICA and FAIR projects under commissioning at the Laboratory of High Energy Physics in JINR. More than 480 magnets will be tested at 6 benches of the facility in the next 4 years. Magnetic measurements for first of serial NICA booster dipole are done. Measured parameters of the magnet fulfill the technical specification.

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