ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI089

FACILITY FOR ASSEMBLING AND SERIAL TEST OF SUPERCONDUCTING MAGNETS

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Abstract

The NICA/MPD project has been started at the Joint Institute for Nuclear Research (JINR) in Dubna in 2007. The NICA accelerator complex will consist of two injector chains, the new 600 MeV/u superconducting (SC) booster synchrotron, the existing SC synchrotron Nuclotron, and the new SC collider having two rings each of 503 m in circumference.

The building construction of the new test facility for simultaneous cryogenic testing of the SC magnets on 6 benches is completed at the Laboratory of High Energy Physics. Premises with an area of 2600 m^2 were prepared to install the equipment. The 15 kA, 25 V pulse power supply, the helium satellite refrigerator with capacity of 100 W were commissioned first bench for magnets testing is now under assembling. First magnets cryogenic tests are planned on July. Start of the serial production of the SC magnets for the booster synchrotron is planned for the end of 2014.

INTRODUCTION

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

The first magnets for the NICA booster and collider have successfully passed cryogenic test on the bench [4]. Three pre-serial dipole magnets for the NICA booster will be tested in 2014. These tests include measurements of the magnetic field quality. Serial production of magnets for the booster is scheduled for the end of 2014. Serial production of magnets for the NICA collider is scheduled for 2015 [5].

SIS100 is now in the procurement phase with the start of the dipole series production [6]. The integration of the already designed quadrupole modules is now detailed. The quadrupole and corrector magnets will manufactured in the joint GSI-JINR collaboration. The design of the doublets was done by GSI. The units (quadrupole plus associated correctors) will be manufactured and tested by JINR. 3 of 6 benches planned to be available for the testing of the SIS100 quadrupole units [7].

PURPOSE AND SPECIFICATIONS OF THE FACILITY

The facility is designed for round-the-clock operation. Following magnets will be assembled and tested at the facility:

- 40 dipole magnets for the NICA booster;
- 48 quadrupole magnets with multipole correctors for the NICA booster;
- 175 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.

The tests are scheduled in two stages. At the first stage dipole and quadrupole magnets for the NICA booster will be tested as well as pilot magnets for SIS100 and the NICA collider. One test bench will be allocated for tests of pilot sample magnets for SIS100 and the NICA collider. The magnets for the NICA booster are envisaged to allocate three terminals (two for dipole magnets and one for doublets of quadrupole 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.

In the second stage operation serial quadrupole magnets for SIS100 will be tested as well as serial dipole and quadrupole magnets for the NICA collider. At this stage it is necessary to increase the number of test benches from 4 to 6 (3 for quadrupole magnets of SIS100 and 3 for dipole and quadrupole magnets of the NICA collider).

Operating simultaneously on 6 benches one need about 30 months to test all magnets for SIS100 and the NICA collider with an average rate of testing of 17 magnets per month, of which only 4 or 6 magnets will require retests.

DESCRIPTION OF THE FACILITY

The premises with an area of 2600 m^2 were prepared at the Laboratory of High Energy Physics JINR the equipment installation. The location of the equipment at the test facility is shown in Figure 1.

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Figure 1: 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.

The equipment for cable production allows producing a Nuclotron-type hollow composite superconducting cable with the capacity of up to 50 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.

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.

The place for the assembling of the magnets is equipped with a few tables and tooling for rotating the magnet round the longitudinal axis to ease welding and brazing the cooling channels, devises for electrical insulation test, resistance and inductance measurement, hydraulic of cooling channels test and adjustment.

The place for “warm” (room temperature) magnetic measurements is equipped with magnetic measurement system (Fig. 2), pulsed linear regulated power converter with the current up to 100 A and DAQ based on National Instruments PXI measuring electronics and LabVIEW software.

Supply current is measured by a current transducer (DCCT) LEM ITZ 600-SBPR FLEX ULTRASTAB. The rotation of stepping search coils is performed by means of a Mitsubishi servo motor HP-SF1024B and a servo amplifier MR-J3100A4. The magnetic measurement system consists of 5 sections. Each section comprises three radial measuring coils made as multi-layer PCB and consists of 20 layers with 20 turns in a layer. Rotation from one section to another is transmitted by a non-metallic Cardan shaft. The above mentioned equipment is intended to measure the quality of the magnetic field in the aperture of the magnet using a Fourier analysis method with a step-driving search coil.

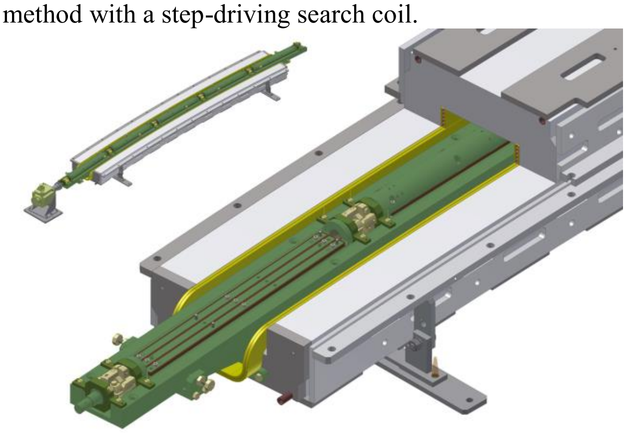

Figure 2: 3d-model of the sensor used in the magnetic measurements in NICA booster curved dipoles.

Detailed description of the magnetic measurements technique is presented in [8].

The place for checking vacuum tightness of the cooling channels, beam pipes and cryostats is equipped with tables, vacuum chambers, a pumping system, a leak

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detection system and a helium high pressure system. The vacuum system is based on diffusion pumps PDI250-W HSR, rotary vane pumps DUO35, TPR280 and IKR251 gages produced by Pfeiffer Vacuum, a helium leak detector, manometers, valves and reducers.

The place for assembling magnets in cryostats is equipped with two tables, tooling for mounting, adjustment and fixing the magnets in the cryostat, devices for mounting and verifying the temperature sensors and voltages taps.

Hall for cryogenic tests of the magnets will be equipped with 3 helium satellite refrigerators (HSR) (Fig. 3), 6 feed boxes with 12 HTS current leads [9] 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 superconducting magnets simultaneously at 6 benches and is planned to be used for testing of NICA (booster, collider) and FAIR (SIS100 synchrotron) superconducting magnets. For the moment 1st HSR (made in ILK Dresden) commissioned, fully tested and ready for operation.

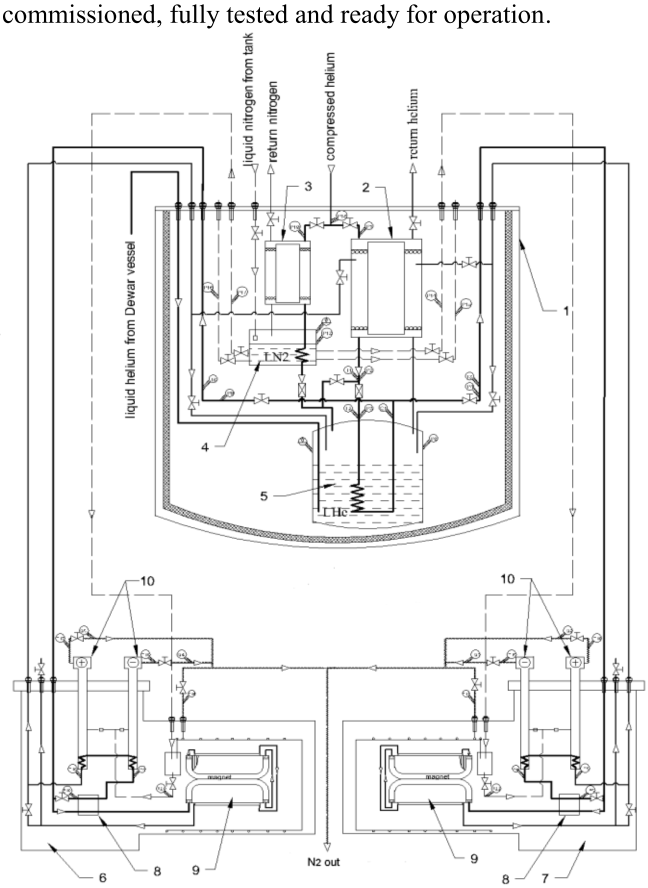

Figure 3: Flow diagram of two test benches: 1 - vacuum shell of the satellite helium refrigerator; 2 and 3 – main and starting heat exchangers; 4 – bath with liquid nitrogen, 5 – bath with liquid helium, 6 and 7 – left and right feed boxes; 8 – subcooler of liquid helium flow; 9 – SC magnet; 10 – HTS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

Facility will be equipped with two power converters on 15 kA DC, 25 V for parallel operation of 6 benches. The first power converter is made in EVPU a.s. (Nova Dubnica) and commissioned in November 2013.

CONCLUSIONS

The first stage of the new facility for testing SC magnets is commissioned in the Laboratory of High Energy Physics, JINR. Testing of the 1st bench is scheduled on July this year. The facility is constructed by joint efforts of GSI and JINR to test SC magnets for the NICA project in Dubna and the FAIR project in Darmstadt. Start of the serial production of SC magnets for NICA booster is planned at the end of 2014. More than 430 magnets will be tested at 6 benches of the facility in the next 4 years.

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