DEVELOPMENT OF TEST FACILITY FOR HED@FAIR QUADRUPOLES*

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Abstract

Superconducting wide aperture high gradient quadrupoles for final focusing system of the HED@FAIR beamline are developed as a part of the collaboration contract between FAIR and NRC ”Kurchatov Institute”–IHEP. Before the shipment to FAIR all manufactured quadrupoles are need to pass Factory Acceptance Tests (FAT) including cold tests to ensure that they are complied with contract specifications. Test facility for cold test of these quadrupoles is created at NRC ”Kurchatov Institute”–IHEP. General description of test facility and information about its design and main characteristics are presented in the article.

TEST FACILITY

The HED@FAIR collaboration plans to generate high-energy-density states of matter using the intense heavy ion beams provided by the SIS 100 synchrotron of the FAIR facility [1]. For these experiments, it is necessary to deposit all the beam energy in the shortest possible time, i.e. to compress the ion bunch and to focus the ion beam down to a spot of one mm. Therefore, the final focusing system (FFS), containing the superconducting magnets is the most essential component of the HED@FAIR experimental installation. The proposed focusing system will have four superconducting wide aperture high gradient quadrupoles.

QUADRUPOLE MAIN REQUIREMENTS

The main characteristics of the quadrupole [2] are as follows: DC operating mode; the coil inner diameter is 260 mm; 2 m length 37.6 T/m central field gradient, 5.7 kA operating current, 5.9 T maximal field in the coil, 1079 kJ storage energy. Cold mass of quadrupole is about 6.5 tons. The cross section of the quadrupole is shown in Fig. 1.

PROGRAM OF QUADRUPOLE TEST

During the Facility acceptance test (FAT) [3], quadrupole must pass following procedures:

- Insulation Test – min. twice the operation voltage plus 500V during 2 min. between coil and vacuum vessel at room temperature.
- Vacuum tests on the cryostat at room temperature.
- Quadrupole cooling down.
- Vacuum tests on the cryostat after the quadrupole cooling down.
- RRR measurement of the coil during cooling down.

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- Insulation Test – min. twice the operation voltage plus 500V during 2 min. between the coil and the vacuum vessel after cooling down to 4.5K
- Critical current measurement of the quadrupole at the ramp rate of 10A/s up to value by 10% higher than nominal current.

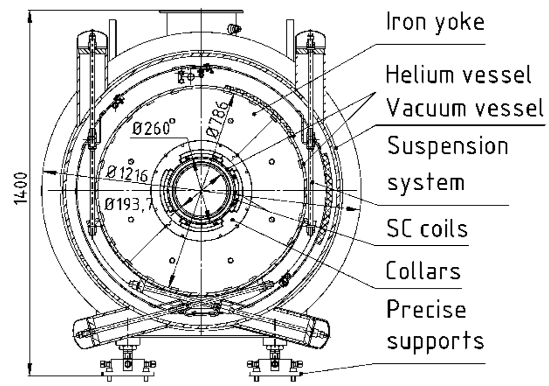

Figure 1: Cross section of the quadrupole.

- Magnetic measurements of central and integral multipoles at the nominal current.
- Measurements of the central gradient, constant of the magnet, the central integral field and the effective length of the quadrupole.
- Quadrupole operating at the nominal current for one hour.
- Quadrupole warming up.

TEST FACILITY DESCRIPTION

Test facility is needed to provide all these tests and ensure that quadrupole fulfils all criteria of FAT. It is also important to obtain all the necessary experimental data about the state of the quadrupole in real time, during the tests. General scheme of facility is shown in Fig. 2. Tested quadrupole is cooled by the satellite refrigerator [4]. Liquid helium for the satellite refrigerator is supplied by industry made cryogenic plant with liquefaction capacity up to 150 l/hr. Due to the large diameter of the quadrupole cold mass it is possible that intolerable stress could occur in the parts of the helium vessel during cooling down or warming up. To prevent it cooling down will be done in steps. Initially the inlet helium temperature will be 220 K. After all the cold mass is at 220 K, inlet helium temperature will be 60 K. Finally, the quadrupole will be cooled by liquid helium. In the same way will be arranged the warming up procedure. At the first step of warming up the inlet helium temperature is to

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be about 160 K, at the second step 240 K and at the last step 290 K.

Quadrupole thermal shields will be cooled by liquid nitrogen. In case of emergency shutdown or quench, all current flows through external dump resistor, and evaporated helium from quadrupole goes to quench receiver.

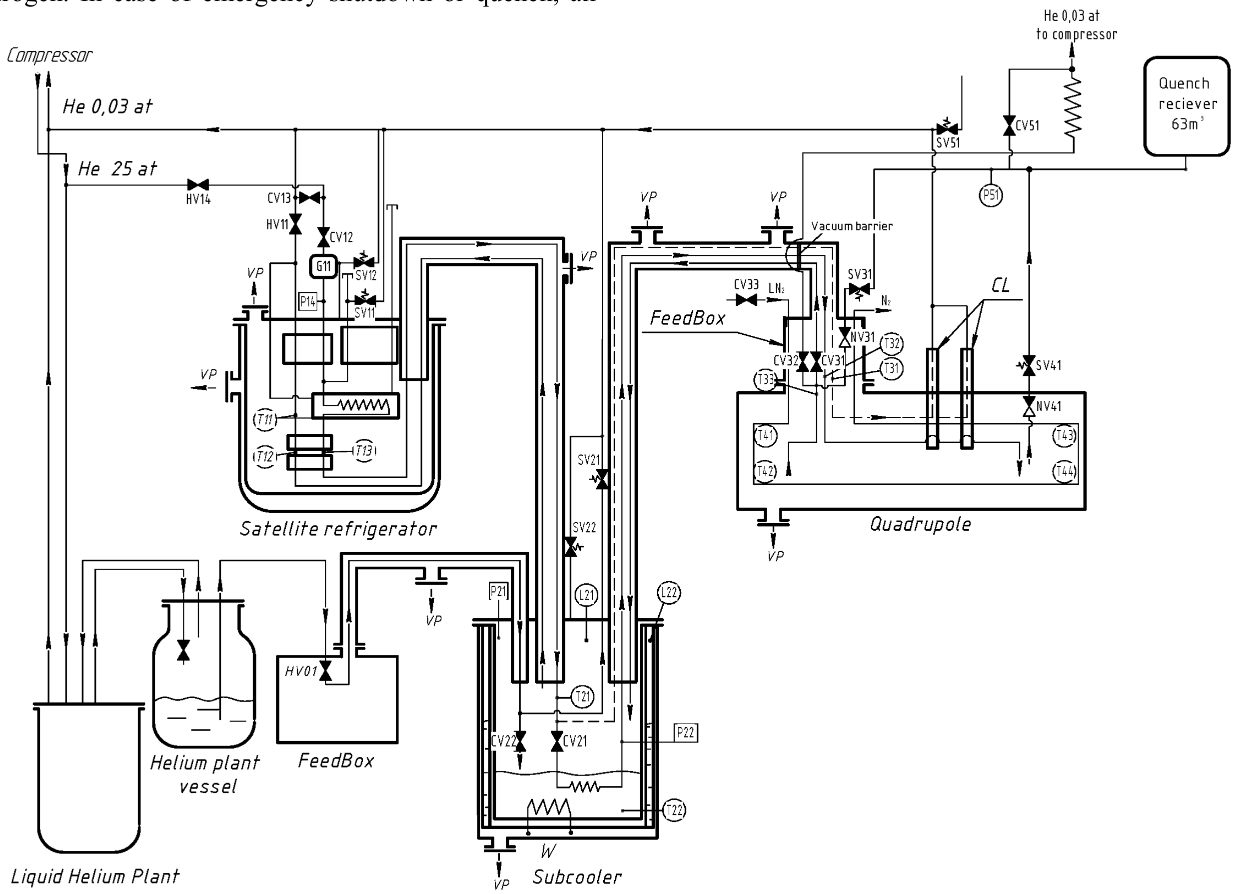

Figure 2: General scheme of quadrupole test facility. T11-T44 – thermometers, P14-P51-pressurse gauges, L21-liquid helium level meter, L22 – liquid nitrogen level meter, G11 –vortex flow meter, HV– manual valves, CV - remote controlled valves, SV – safety valves, VP – vacuum pumps, W – heater, CL – current leads.

Each one of facility parts should provide the personnel with information about their current state, such as pressure, liquid nitrogen and helium levels, helium flow, current temperature, and degree of vacuum, and allow controlling their state according to the operation algorithm. In order to obtain this information, various types of gauges and sensors are mounted on the stand, information from which is collected and transmitted to the PC-based operator control and monitoring system for visualization and operator control of processes.

SENSORS AND ACTUATORS

Amount of measured signals is performed in Table 1.

Table 1: Test Facility Measured Points

Type of signal	Amount
Temperature	12
Pressure	3
Vacuum	5
Valves position	16
Level meters	2
Flowmeter	1

Thermometers T21,T31, T32 and T33 (Fig. 2) are calibrated TVO resistive temperature sensors. T41, T42, T43, T44 mounted on quadrupole are CLTS-2B linear temperature sensors. The rest thermometers are platinum temperature sensors.

Pressure is measured by intellectual pressure gauges with HART interface and output signal 4-20mA.

Vacuum measurements provides by two types of sensors, first one for the range 5x10-1−1x10-4, and the second for upper vacuum levels. First range is measured by thermocouple vacuum gaugesю High vacuum is measured by gauges, which are using Pirani technology.

Valves with code HV (Fig. 2) have manual actuator, valves with code CV have pneumatic remote controlled actuator with 0-5mA interface for the connection with a controller.

L21 is superconducting helium level sensor, and L22 is liquid nitrogen capacitive level sensor. Both are connected to 2-channel liquid cryogen level monitor.

Flowmeter G11 is performed by vortex-based model with 4-20mA interface.

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The listed signals do not include the electrical and magnetic measurements of the quadrupole, quench control sensors, which will be represented separately.

HARDWARE PART

Key part of hardware is the Compact RIO system controller with a processor and user-programmable FPGA, which is populated with nine I/O modules from National Instruments. These modules provide direct sensor connectivity and specialty functions. In this case system consists of four NI9219 and four NI9265 modules.

The NI-9219 module [5] can measure signals from sensors such as resistance temperature detectors (RTDs), thermocouples, strain gages, load cells, and other powered sensors, as well as make quarter-bridge, half-bridge, and full-bridge current measurements, with built-in voltage and current excitation.

The NI-9265 is using for interfacing and controlling industrial current-driven actuators at high rates. This module allows controlling position of facility valves.

Besides Compact RIO system, hardware part of test facility consists of independent analog input/output modules of MV110 type. These modules are mounted in a separate rack, collect data from pressure and vacuum sensors, and send it to the operator PC through rs-485 to USB converters AC-4. Level meters are equipped with liquid level monitor with RS-485 interface and connected to operator PC directly.

SOFTWARE

Software part of test facility is based on Labview 2014 engineering software, with NI-DAQmx drivers and Compact RIO drivers. That development environment helps to organize single control system application, using hardware from different vendors. Compact RIO chassis with plugged modules is connected to the system by standard Ethernet port and NI remote system explorer. Side hardware is connected to the diagnostic system by USB and COM ports, using Data socket technology and OPC servers. Graphic panel represents all necessary parameters of the facility in order to control cooling down and test processes in real time. Experimental data obtained from sensors will be saved in TDMS file format for the further analysis. After test run, the software part generates report in .doc format, which depends on type of performed test and can include measurements shown in different formats (charts, tables etc.)

CONCLUSION

Test facility for cold tests of superconducting quadrupoles for the strong final focusing system of the HED@FAIR beam line is being developed at the present time. Its main parts are represented in the article. Control system will allows to measure and regulate necessary parameters of the test facility for quadrupole cold test. Hardware and software parts are developed according to Quadrupole FAT requirements. In addition, test facility will help to acquire experimental data about quadrupoles behavior during the cold tests.

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