CONTROL SUBSYSTEM FOR NUCLOTRON CRYOGENICS

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Abstract

The Nuclotron, a superconducting synchrotron was put into operation in March 1993 at the Laboratory of High Energies, Joint Institute for Nuclear Research. The cryogenics subsystem of the Nuclotron Control System [1] is described in this paper. The subsystem provides temperature measurements of the Nuclotron elements at more then 600 control points. The measurement range is from 4 to 300 K with a resolution of 25 mK at a temperature of 4 K. Carbon resistors are used as temperature sensors. The subsystem measures:

- helium pressure in both supply and return lines
- helium and nitrogen levels in the separators
- helium and nitrogen pressure in the separators and storage tank
- the mass vapour content of helium in the supply headers.

The subsystem has been implemented utilizing hardware interface is CAMAC and PC.

1 INTRODUCTION

The superconducting synchrotron named Nuclotron [2] was put into operation at the LHE JINR in 1993. It's purpose is to accelerate nuclei and heavy ions. The maximum energy of particles with the charge to mass ratio Z/A=1/2 is 6 GeV /u. The 250 meter ring of the Nuclotron comprises 96 dipole magnets and 64 quadrupole lenses, forming the FODO lattice with 32 periods. There are no dipoles in every 4-th period , i.e. the Nuclotron structure forms 8 superperiods with two free spaces in each. At present the slow extraction system is being commissioned almost for all the Nuclotron energies. The planned extraction duration is 0,5…10 s.

The cryogenic system [3] (see Fig.1) consists of two subsystems. Each of them is supplied with a separate refrigerator connected to its half-ring and operates independently. Liquid helium entering the supply header of the half-ring cryostat, is distributed over the cooling channels of parallel connected individual units (magnets and lenses). In each unit, the two-phase helium flows through the cooling channels of the superconducting buses, the windings and the iron yoke. Each subsystem contains a nitrogen channel for cooling the 490-mm diameter shield surrounding the structure elements of the Nuclotron ring.

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2 GENERAL DESCRIPTION

There are more than 600 of measurement points in the cryogenics subsystem. The structure dipole and quadrupole magnet sensors are placed at the inlet and outlet of the windings and at the entrance of the return header. The other sensors are placed in the inflector septum-magnet, on the nitrogen shield and in some nonstructural elements of the ring.

It is necessary to shield the cabling from electromagnetic noise because of the considerable distance of the sensors from the measuring equipment (50-100 m) and their proximity to RF sources.

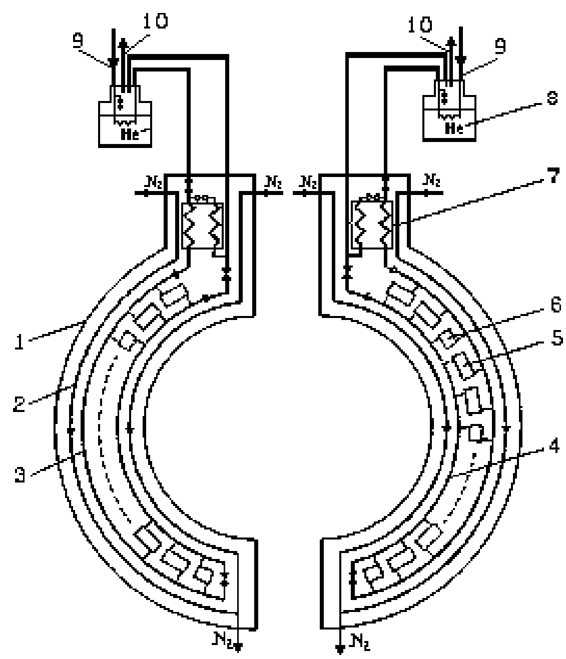

Figure 1: General scheme of the Nuclotron cryogenics: 1 - vacuum shell; 2 - heat shield; 3 - supply header; 4-return header; 5-dipole magnet; 6 -quadrupole magnet; 7-subcooler; 8 - separator; 9 - helium flow from the refrigerator; 10- return helium flow to the refrigerator;

A measurement accuracy of ≈ 1K is tolerable at the beginning of the cooling process, when the temperature of the cooled elements is about ≈ 290 K. Under operating conditions at the cryogenic temperature the measurement accuracy is 0.05K. Commercial carbon resistors TVO [4] of ~1 kOhm at room temperature and ~4 kOhm at the cryogenic temperature are used as temperature sensors.

The resistance dependence on element temperature is described by the 7-th power polynomial. To obtain the coefficients of the polynomial, 8…10 calibration points were taken over a temperature interval of 4…300 K for every sensor.

3 MEASUREMENT SCHEME

The cryogenics control system of the Nuclotron is based on an industrial PC computer from ADVANTECH, connected to the Nuclotron local area network. The measuring and auxiliary electronics utilizing PC and CAMAC is located in the data acquisition room at the center of the LHE accelerator complex approximately ~ 50 m from the temperature sensors.

All the temperature sensors are divided into 10 independent measuring circuits. The sensors of each circuit are connected in serial and supplied with separate current sources with the output impedance 10^{11} Ohm. A current of 10 μA is used to minimize sensor heating.

Ten integrating 16 bit AD1170 ADCs with a 20 ms conversion time are used for digitizing sensor signals. The ADCs are mounted on two PC boards developed and manufactured at LHE. The system is divided into 10 subsystems. Each subsystem contains 64 resistors (60 thermoresistors and 4 calibration resistors), one 64 channel multiplexer and one ADC. An acceptable signal to noise ratio is achieved with sensor signal amplitudes of 10…50 mV. The CAMAC 64-channel multiplexer has an output differential amplifier with 80 dB common mode rejection and a gain of 100.

Each subsystem includes 4 precise resistors connected in series with the thermoresistors. This allows an automatic calibration of the measurement system in every cycle of the Nuclotron.

4 MEASUREMENT AND DATA PROCESSING

The system software consists of two C++ programs. The first, performs measurement of cryogenic system parameters, processing of information, and the storing of results on the network server disk. The second program allows current and archive information to be displayed on any Nuclotron local area network computer.

As the measuring time is 1.4 s, the measurements can be performed between Nuclotron magnetic cycles. This results in reduced noise pickup from the Nuclotron RF system.

Under operating conditions, temperature measurements exceeding 9 K for the helium sensors and 90 K for the nitrogen sensors causes an alarm signal and prohibition of the Nuclotron cycle.

To optimize the cryogenic system operation, it is necessary to measure other parameters of the system. The subsystem measures:

- helium pressure in both supply and return lines
- helium and nitrogen levels in the separators
- helium and nitrogen pressure in the separators and storage tank
- the mass vapour content of helium in the supply headers.

Absolute and differential manometers are used for temperature measurements. These sensors are read by a 13 bit integrating ADC. Helium levels and mass vapour content measurement is accomplished using a resonant circuit where the resonant frequency changes based on the dielectric permeability of the medium being measured.

The measurement results are written to a current data file on the network server disk located in the central Nuclotron control room. Every 30 minutes, data is written to an archive file on the server disk. The operator can save data to an archive file at any time.

In a special “express-mode” the measurements are performed with period of 50…100 ms for a few sensors . The operator select the sensors to be monitored from the front end computer keyboard. In the “express-mode” the selected measurements are displayed on the front end computer screen.

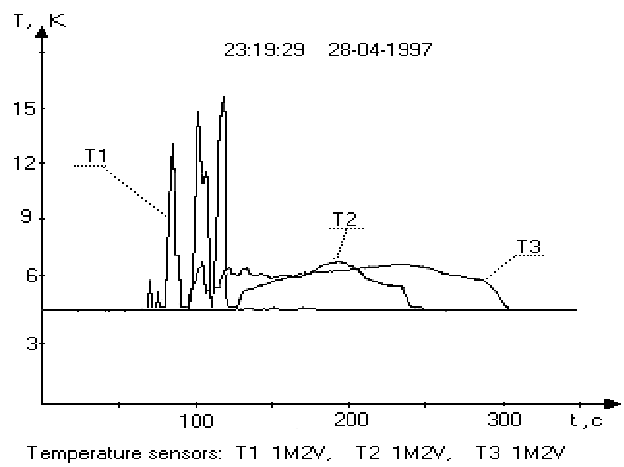

Fig.2: Measuring results for 3 sensors in the “express-mode”.

Fig. 2 illustrates the system operation in the “express-mode”. The dipole magnet winding was heated for ~10 s at the inlet of the winding. Sensor T1 is located near to the point of heating, T2 is further along the helium flow at the winding outlet and sensor T3 is located at the return header.

5 DATA DISPLAY

After data processing and transfer to server disk, the information is displayed on the front end computer screen, and is broadcasted to different Nuclotron services using the ICTM interface developed at LHE. The program cycle time is ≈5 s.

Any Nuclotron local area network computer can display the measurement result. The LAN computer also has access to all the archive files from previous Nuclotron runs. Data display is controlled with the help of a dialogue menu in this program.

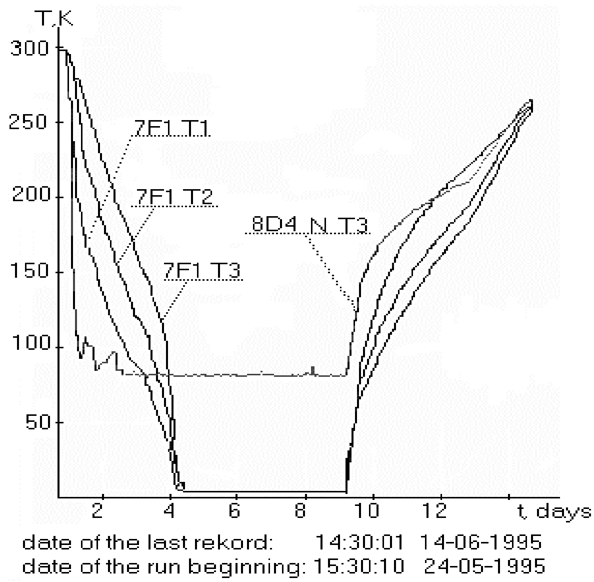

Fig.3: Temperature change for 4 sensors during the Nuclotron run.

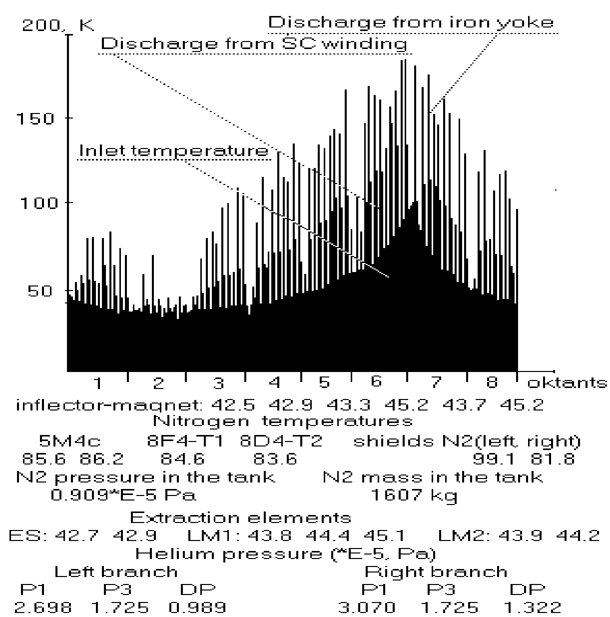

Fig. 4. Temperature distribution along the Nuclotron ring (24 hours from the beginning of run).

Fig 3 shows the temperature change of 4 sensors during Nuclotron run in May-June 1995. The sensor 8D4 N T3 shows the nitrogen shield temperature near one of the lenses D; the other 3 sensors are located in the cooling channel of one of the dipole magnets. The temperature distribution along the Nuclotron ring elements 24 hours after beginning cool down is shown in Fig. 4. The Nuclotron operating conditions are met when the temperatures of all the elements reach ≈ 4.5 K. The total cool down time is ≈ 80 hours.

6 CONCLUSION

The cryogenics control subsystem has been operating since the first Nuclotron run in March 1993, and has been improved continuously. In 1999 temperature measurement of the extraction system elements – electrostatic septum (ES) and two Lambertson magnets (LM1 and LM2) were added.

7 REFERENCES

[1] V.Andreev et. al., Proc. 1997 Part. Accel. Conf., p. 2452.
[2] A.M.Baldin et. al., IEEE Trans. Nucl. Sci. 1983, p. 3247.
[3] A.M.Baldin et. al., Cryogenics of the new superconducting accelerator Nuclotron. E8-95-65, Dubna, 1995.
[4] V.I.Dackov et. al., JINR, 10-81-200, Dubna, 1981.