ORIGINAL PAPER

TEST STAND OF THE TECHNOLOGICAL SYSTEM OF THE CRYOGENIC MODERATOR WITH THE CONTROL ELECTRONICS*

SERGEY KULIKOV[1], V. ANANIEV, A. BELYAKOV, A. BOGDZEL, M. BULAVIN, A. VERHOGLYADOV, E. KULAGIN, A. KUSTOV, K. MUKHIN, A. LUBIMTSEV, T. PETUKHOVA, A. SIROTIN, A. FEDOROV, E. SHABALIN, D. SHABALIN, M. SITNIK, V. SHIROKOV

Manuscript received: 26.07.2011; Accepted paper: 10.08.2011

Published online: 01.09.2011

Abstract. *In investigations of compound structures within the framework of condensed matter it is possible to obtaine more experimental results using cold neutrons. The use of cold neutrons makes it possible to measure diffraction peaks with good resolution and statistic at long wavelength that is very important in studying magnetic structures, multiphase samples, etc. The role of the cold neutron source at the IBR-2M reactor will be ascribed to the cryogenic pelletized moderator. This moderator represents a chamber filled with the working substance in the form of frozen beads made up of a mixture of aromatic hydrocarbons (mesytilene + m-xylol). The beads are delivered to the chamber through the pipeline by a flow of cold helium at the temperature of 30 – 40K. The major problem of moderator operation here occurs in relation to the pneumotransport system of the beads delivery. To solve the problem the special model of moderator was created and there were carried a number of experiments on loading the chamber-imitator and on optimization of operation of the basic technological units and systems with electronics for management and control.*

Keywords: *moderators, neutron scattering, vacuum, electronics.*

1. INTRODUCTION

Cryogenic moderator based on aromatic hydrocarbons at the powerful pulsed research reactor IBR-2M will be a unique pulsed cold neutron source with the wave length of more than 0.4 nm, laying the grounds for scientific investigations based on neutron scattering techniques on the level of the global present-day standards. Cryogenic moderator will be a part of a complex of neutron moderators at the IBR-2M reactor /1-8/.

Cryogenic moderator facility includes cryogenic moderator itself - the chamber filled with working substance (aromatic hydrocarbons - mesitylene + m-xylol - in the form of frozen beads), the system of beads preparation and loading the chamber, the system of replacement of the exhausted working substance, the chamber cooling system alongside the temperature stabilizing system for keeping the temperature of the beads at the level of 30 K, and other auxiliary systems providing normal work of cryogenic moderator.

Cryogenic moderator represents a rather complicated technical structure whose elaboration requires the stage-by-stage method of dealing with specific methodological and engineering problems. One of the high-priority objectives is loading the moderator chamber

**** Presented at 3rd Joint Seminar JINR-Romania on Neutron Physics for Investigation on Nuclei, Condesed Matter and Life Science, 24-30 July 2011, Targoviste, Romania.***

[1] Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia.. E-mail: ksa@nf.jinr.ru

with the frozen beads. The principle we choose here is transportation of beads by cold helium (40K - 80K) out of a special charging device through the extended pneumoline to the chamber. The transportation problem consists in the absence of both the experimental and theoretical data on elastic-plastic, adhesive and tribological properties of solid amorphous mesytilene (that is the mixture of 70% mesytilene with m-xylol), along with the data on movement of a single ball through a wide cylindrical pipe, taking into account the rolling and sliding friction, as well as the deviations from sphericity. All this made it difficult to calculate the parameters of the pneumotransport system and to develop the charging device. Therefore the transportation problem had to be solved experimentally – first, at the special laboratory stand for finding solutions to the problem of a single ball movement /9-11/, and second, at the stand with the cryogenic moderator prototype. In this work it is presented as the test stand of a cryogenic moderator for investigations of properties of a cold line for loading solid frozen aromatic hydrocarbons (mesitylene, m-xylol) in the form of beads.

The purpose of elaboration of the stand and its employment in scientific research is providing arguments for the accepted principle of delivery and loading of the working substance based on aromatic hydrocarbons into the cold moderator chamber, and making the functional check of the technological systems.

By now, the following work has been fulfilled at the test stand of the cryogenic moderator of the IBR-2M reactor:

- 100% loading of the chamber-imitator (~ 1000 ml of beads or 27000 beads with diameter 3.5 - 4 mm), has been completed;
- adjustment of the control system has been done;
- the optimal operating temperature of the stand has been defined;
- the operating speed of helium in the internal tube of the pneumoline has been defined;
- the optimal supply rate of the beads out of the charging device has been defined;
- time, required for a complete loading of the chamber-imitator, has been determined.

2. THE TEST STAND OF THE CRYOGENIC MODERATOR

The pneumoline of the moderator test stand has been developed and is put into operation at the 3rd channel of the experimental hall #2 at the IBR-2M reactor. It duplicates the basic units and systems of pneumoline of the actual moderator (Fig. 1).

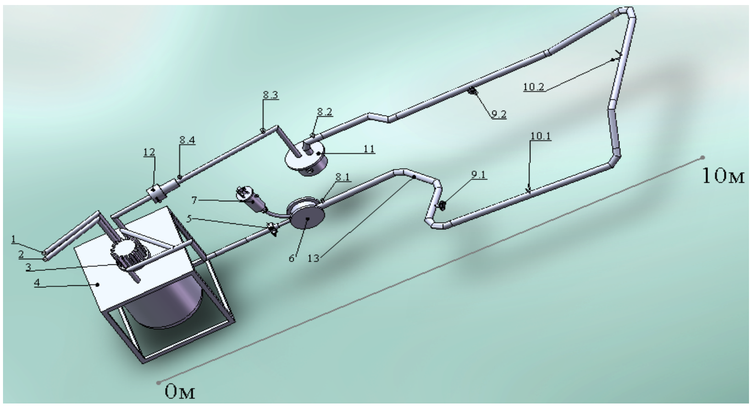

Fig. 1. The three-dimensional scheme of the test stand of the cryogenic neutron moderator of the IBR-2M reactor.

1 - Pipeline for the helium supply to the cryogenic helium machine, 2 - Pipeline for the helium outflow from the cryogenic helium machine, 3 - Blower, 4 - Cryostat, 5 - Pitot tube and vacuum pressure gauge, 6 - T-branch, 7 - Batcher of the beads supply into the pneumotransport pipeline; 8.1, 8.2, 8.3, 8.4 - Temperature gauges of the pneumotransport pipeline; 9.1, 9.2 - Flanges for the vacuum pump out; 10.1, 10.2 - Outlets for the beads motion detectors; 11 - Chamber-imitator of the cryogenic neutron moderator, 12 - System of the helium feeding; 13 - Pneumotransport pipeline.

The principle of operation of the stand consists in the delivery of the frozen beads out of the charging device to the chamber-imitator through the pneumoline by cold helium at the temperature of 30-40K. To prepare the stand for operation in the pneumoline space (beads are transported through the internal tube) and in the cryostat (Fig. 2) it is necessary to create a vacuum of the order of 10^{-4}-10^{-5} Torr.

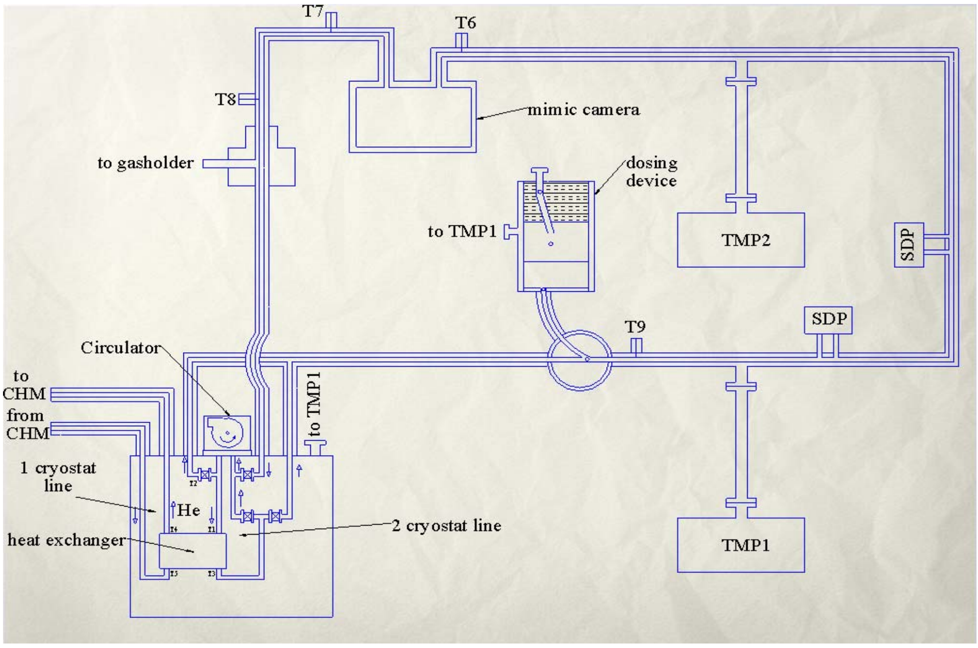

Fig. 2. Technological scheme of the stand of the cryogenic neutron moderator: TMP – vacuum pumps, SDP – sensors of differential pressure, T – temperature sensors.

The internal pipeline is evacuated through the flange of the batcher to get forevacuum in order to remove air and the remaining fragments of mesitylene. The air is pumped out through the special turbomolecular pumps. The amount of vacuum is controlled by the 901–MKS gauge. After obtaining forevacuum the pipeline is filled with helium out of a gasholder at room temperature under the pressure of 1.03 atm. During operation the gasholder is permanently open, which results in keeping the helium pressure in the internal pipe at one and the same level. Cold helium enters the cryostat through the pipeline of its supply from the cryogenic helium machine (CHM-500), after that the temperature in the first contour falls down. Temperatures in the cryostat are fixed by sensors (T1-T5, fig. 2) and are controlled by the computer. After filling the pneumotransport pipeline with helium, the latter starts to circulate through the pneumoline (2nd contour of the cryostat). Due to the heat exchanger, the temperature of the helium in the 2nd contour goes down, gradually forcing the temperature of the internal pipe to go down as well. The temperature in different parts of the pneumoline is fixed by the T6-T9 sensors. After achieving the operating temperatures of 30-40K, it is possible to begin the loading of the chamber-imitator. Frozen beads are placed in the charging device that delivers them into the internal pipe of the pneumoline. With a flow of cold helium the beads are transported to the chamber-imitator, their appearance in the chamber is fixed by a video camera. After the experiment liquid mesitylene is removed from the chamber-imitator through a special drainage system.

3. TECHNOLOGICAL SYSTEM OF MANAGEMENT AND CONTROL OF THE TEST STAND OF THE CRYOGENIC MODERATOR

Now, as the development of the system of management and control of the test stand is completed (Fig. 3), its adjustment and optimization is in progress. All modules of the system are combined into a single unit, located in the experimental hall, while the control and data acquisition are performed remotely from a PC with specially written software.

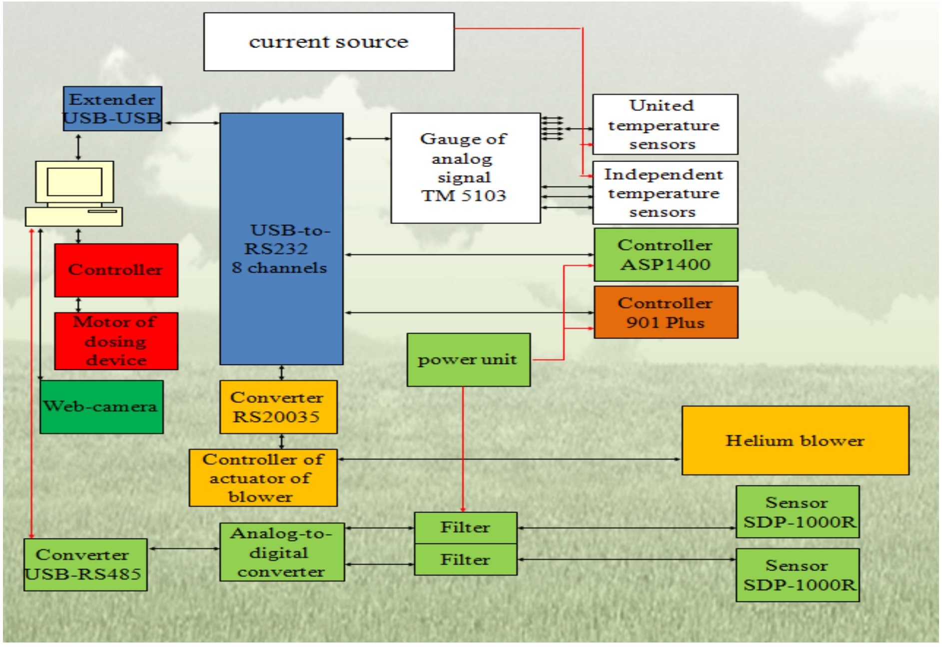

Fig. 3. Architecture of the system of management and control of the cryogenic moderator: ▭ - the temperature control system, ▭ - the vacuum control system, ▭ - the ball detection system, ▭ - the blower control system, ▭ - the motor of the charging device control system, ▭ - the video camera control system, ▭ - the USB-RS232 system and the USB-USB system.

The system of management and control includes:

– modules of temperature and vacuum control,
– module of the gas blower control,
– module of the step motor control,
– module of the video camera control.

3.1. TEMPERATURE CONTROL SYSTEM

To control the temperature a set of 9 series-connected sensors (T1-T9, Fig. 1) is used. The range of temperature measurements is 15K-273K, which corresponds to changes in resistance of the sensors in the range of 1.8-800Ohm. Resistance dependence on temperature is inverse. The required accuracy of temperature measurements is 0.1 degrees. The sensors are connected in a way of the 4-wire circuit, that is one pair of wires is fed with direct current, and the other pair of wires is meant for killing the voltage proportional to the measuring value - the resistance of the sensor. The 8-channel analog signal measuring device TM 5103 was chosen for getting the voltage patterns as they are registered by the sensors. It is used in the mode of cycling display of the measurement results at each of the 8 channels at the main 4-bit panel. The measuring device TM 5103 has a computer communication interface – RS232, which makes possible to connect it to the PC through the communication line of up to 15m.

3.2. BLOWER (HELIUM CIRCULATOR) CONTROL SYSTEM

Blowers (helium circulators) are intended to provide the necessary speed of movement of the working gas in the internal tube. Both the speed of movement of the beads and the time required for the chamber filling depend on the speed of the gas flow and its temperature. On the one hand, the speed of movement of the beads should not be too high, otherwise it would destroy them, and on the other hand, it should not be too small, otherwise the loading time would be inacceptable long. The property of the blower, defining the speed of the gas flow in the pipe, is the motor speed. The Toshiba "VF-S11" device was chosen as a frequency drive for the motors with powers below 400W.

3.3. THE CONTROL SYSTEM OF THE CHARGING DEVICE

The charging device (batcher) is a cylinder with a disk at the base, where frozen beads (Fig. 5) are placed. Cylinder is surrounded by vacuum-nitrogen “jacket” preventing the heat penetration (Fig. 4). The upper flange of the “jacket” has a special opening at the top through which the loading is fulfilled. The disk is connected to a pulse motor by means of a long rod.

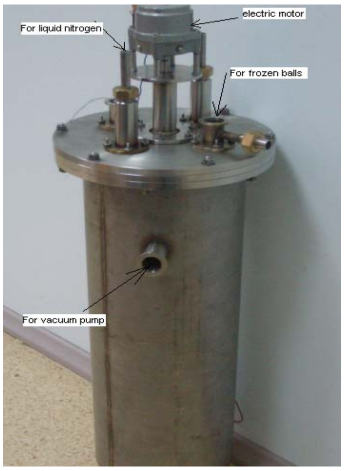

Fig. 4. Charging device.

Fig. 5. Cylinder with a disk.

As a basis for the charging device control system, the Standa controllers of step motors 8SMC1-USBh-B1 were chosen. They allow to adjust the speed of the step motor in a wide range. To insure the smoothness of the charging device operation, the step motor with a reducer 1:150 was chosen thus resulting in the rotating frequency from several rotations per minute to 1 rotation in several minutes. Management and control of the operating parameters such as position, acceleration/deceleration, speed and direction of movement is realized via the USB interface of the PC.

3.4. THE MONITORING CONTROL SYSTEM

The monitoring control system is based on the video camera which is installed at the window of the chamber. It is at room temperature. The installation of some LEDs is necessary to light inner part of the chamber. This camera allows having a view into the chamber during its fulfillment (figs. 6, 7).

Fig. 6. Chamber-imitator of the test stand with glass window and vacuum jacket.

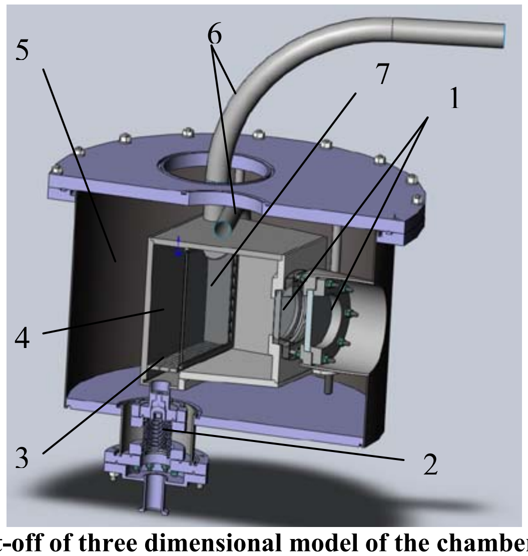

Fig.7. Cut-off of three dimensional model of the chamber-imitator
1 - Thick glass windows, 2- Drainage system, 3 - Grating, 4- Volume for beads, 5 - Vacuum jacket, 6 - Pipes of incoming helium with beads and out coming helium,7 - glass wall.

Fig. 8. Photo of delivered beads in the chamber (18 cm x 18 cm x 4 cm) taken by the video camera (The temperature of beads is about 50 K, amount is about 27000).

The video camera captures the pictures with up to 90 fps and transfers them to the computer through the USB interface. With this system, it is possible to observe the process of beads loading in a real time (Fig. 8) and take the video and photo. The loading time for full chamber is about 8 ours.

4. CONCLUSIONS

At this point nearly 25 experiments on the chamber-imitator loading with beads were carried out at the test stand on the cryogenic moderator. In the course of the experiments, the complete loading of the chamber (nearly 1000 ml of beads) was fulfilled (Fig. 8), the optimal temperature conditions were chosen, the adjustment of the management and control system was done as well as the optimization of the loading modes - particularly, the speeds of helium in the internal pipe and of the beads supply from the charging device were chosen, and also approximate time required for the chamber filling was defined. In the nearest future it is planned to develop the system of counting the exact number of beads in the chamber and the system of control over the possibility of the pipe choked with beads, as well as to work out recommendations on the operation of the actual cryogenic neutron moderator.

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