NEW COMPLEX OF MODERATORS FOR CONDENSED MATTER RESEARCH AT THE IBR-2M REACTOR

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Received September 25, 2008

The operation of modernized research reactor IBR-2M for condensed matter investigation on neutron beams is planning to start in 2010. The new complex of moderators will start operation together with the reactor. This complex will consist of some parts: water pre- and post-moderators, water grooved moderators and three cold moderators. We are developing a technology of utilization of aromatic hydrocarbons as a moderator material for them. There are some reasons of our choice (good moderation properties, resistance to radiation, etc.). The main idea of conception is to load chamber of cold moderator by small balls (4–5 mm in diameter) of frozen aromatic hydrocarbons. These balls will be delivered by helium flow, which will be used as a coolant as well. Use of such a technology gives us opportunity to avoid a lot of problems of radiation effects. Neutron spectra onto beams, project of complex of moderators for the IBR-2M reactor as well as necessity of cold neutron moderators for condensed matter investigation will be presented.

Key words: cold neutron moderators, research reactors, aromatic hydrocarbons.

1. INTRODUCTION

Cold (long wavelength) neutrons have come to play a dominating role in the frontier research carried out with neutrons, and in all likelihood this is going to be even more so in future. A utilization of cold source can improve of many characteristics of experiments on neutron beams. For example (the data have been received in former cold source in Dubna [1]), the diffraction peaks in the range 3–4 Å could not be measured with warm moderator (Fig. 1 a, b).


Altogether, a production of neutrons with long wavelength requires special low temperature moderators. Currently, the standard cold moderators used in high power neutron sources are based on circulating liquid or supercritical hydrogen to ensure satisfactory heat removal and absence of radiation damage. The main deficiency of these moderators is their low hydrogen density which results in moderately high neutron flux. Other perspective hydrogenous materials suffer bad radiation resistance. Nevertheless, together with appropriate neutron moderation properties of aromatic hydrocarbons (mesitylene and its mixture) their hardness to neutron and gamma irradiation at low temperature have been proved [2–4]. The data libraries for this material at different conditions have been prepared by group of Dr. Granada [5]. The availableness of such libraries give us opportunity to make a Monte Carlo optimization of the IBR-2M research reactor complex of moderators. It is consist of warm (ambient water moderator) and cold (aromatic hydrocarbons base moderator) parts.

2. RESULTS OF NEUTRONIC CALCULATIONS OF COMPLEX OF MODERATORS FOR THE IBR-2M REACTOR

The modernized reactor IBR-2M will start operation in 2010 with the new complex of neutron moderators. It will consist of pre-moderators, three cold
moderators and water grooved moderators (see Fig. 2). The optimization of complex was performed earlier by Monte Carlo simulations [2].

Aromatic hydrocarbons (mesitylene and its mixture) have been chosen as a material for cold moderator as the most proper for conditions of the IBR-2M. The molecule of mesitylene has the benzol ring and three CH$_3$ groups (see Fig. 3). As it was already mentioned it has a good resistance to radiation [2] and good neutron moderation properties [3]. The charging of moderator will be done by mesitylene beads (4–5 mm diameter), which are prepared before the charging. It is necessary to deliver about 10000 beads to fill a moderator. An estimated density of filling of the moderator
volume by beads is about 60%. Utilization of beads gives opportunity to avoid destruction of the moderator chamber due to internal pressure of radiolytic hydrogen stored during irradiation.

The detailed calculation of moderator complex for direction of beams #7, 8, 10, 11 have been successfully finished (left side see Fig. 1). The 3D view to the moderator complex from the sight of beam #7 is in the Fig. 4. Such a composition, in spite of its complexity, gives more flexibility for neutron instruments situated on these beams. Depending on orientation of neutron guides, it is possible to have either more cold or warm neutrons in spectra on a sample. Calculated neutron spectra for the beam #7 is in Fig. 5.
3. TECHNOLOGICAL SCHEME FOR COLD MODERATORS

The mesitylene beads will be delivered to the volume of moderator and after the IBR-2M operational cycle (usually two weeks) they will be melted and moderators refilled. This is a first step to continuous technology of utilization of solid materials for cold neutron moderators. The next step would be to exchange pieces of materials inside moderator without melting.

As it was mentioned earlier, we are planning to use aromatic hydrocarbons inside the cold moderator in solid condition as separated beads, which are delivered by helium flow through the existing biological shields. Transport tube is about 20 m length for each of moderators. The dimension of cold moderators is $18 \times 20 \times 4$ cm (see Fig. 6). There is a grating inside a moderator vessel which holds beads during working time, allowing helium gas to flow through it and in the same time allowing melted mesitylene to pour out into a collector afterwards.

![Fig. 6. – Vertical cut-off of cold moderator of left direction (1 – Helium and balls input, 2 – Helium output, 3 – Vacuum jacket, 4 – Mesitylene beads, 5 – Grating, 6 – Mesitylene discharge pipe, 7 – Flat Water moderator, 8 – Water grooved moderator)](image)

The cooling system is based on a cold helium gas which flow is divided into two loops. Two refrigerators will provide enough cooling capacity for three cryogenic moderators. One of them (700W) is for two side cold moderators and one
Estimated heat load to each of a cold moderator is about 350W which includes radiation heat in the moderator and external heat to all cryogenic parts of the technological scheme.

The principal scheme of a cold moderator and its equipment is shown in the Fig. 7. Beads are dosed into the charging tube (2) from the charging device (3), and then delivered down to the moderator (1) by flow of helium gas which circulates by helium blower (6) through the loop from heat exchanger (5) to the moderator. Two helium loops (one from the cryogenic machine (4) to heat exchanger (5) and another one (7) from heat exchanger to the moderator) prevent of the cryogenic machines from pollution by mesitylene. The helium will cool down beads during the moderator operation as well. After several days of operation the helium blower is switched off, beads melted and the liquid is collected in the receiver (8) through discharging pipeline. The moderator can be recharged afterwards.

The preliminary work for the project of moderator complex of the IBR-2M reactor is finished (material and technological schemes for cold moderators have been chosen, optimization of geometrical parameters of complex of moderators have been done, devices for mesitylene beads preparation are manufacturing, charging tube parameters have been calculated and experimentally checked, development of technological
scheme and purchasing of its main parts have been done). At the first stage, the left part of moderator system will be manufactured and installed at the IBR-2M (see in Fig. 2.). It will be the world first operation of pelletized cold neutron moderator.

The modernized reactor IBR-2M with new moderator complex gives increasing in neutron intensity for extracted neutron beams versus IBR-2 (Table 2).

<table>
<thead>
<tr>
<th>Neutron beam #</th>
<th>Gain on neutron intensity IBR-2M / IBR-2</th>
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<tbody>
<tr>
<td>7 (cold)</td>
<td>4.8</td>
</tr>
<tr>
<td>7 (thermal)</td>
<td>1.7</td>
</tr>
<tr>
<td>8 (cold)</td>
<td>16.8</td>
</tr>
<tr>
<td>10 (cold)</td>
<td>3.5</td>
</tr>
<tr>
<td>10 (thermal)</td>
<td>1.7</td>
</tr>
<tr>
<td>11 (thermal)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

**Acknowledgements.** The authors are grateful to Dr. R.J. Granada’s scientific group for mesitylene cross section libraries and Dr. A. Balagurov for his example of experimental results of diffraction with cold source.

REFERENCES
