STUDY OF THE PHYSICAL CONSTANTS OF A URANIUM GRAPHITE REACTOR LATTICE BY MEANS OF A SUB-CRITICAL ASSEMBLY


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It has been shown experimentally that it is possible to study the physical constants of the uranium graphite reactor lattice by means of a subcritical assembly.

The assembly consisted of a uranium graphite lattice of natural uranium rods for a mockup of the lattice of the Beloyarskii GRES type reactor. The subcritical assemblies were placed in the central part of a uranium graphite reactor using tubes of 2% enriched uranium rods. Experiments are described which showed that it is possible to measure the physical parameters of the reactor lattice, namely, the resonance escape probability \( \phi \), the fast neutron multiplication \( \mu \), and the thermal utilization \( \theta \). Together with the assembly the reactor constituted a critical system. The subcritical assembly was part of the lattice of the reactor under study. The results of the measurements given are in satisfactory agreement with the calculational data.

Introduction

It is of practical importance in many cases to see whether it is possible to measure the physical parameters of a reactor lattice by means of a subcritical assembly. This makes it possible without building expensive critical assemblies to use one and the same test reactor to measure the physical parameters of various lattices under consideration and design by simply changing the subcritical assemblies.

In order to see whether or not it was possible to measure the physical parameters of the lattice by means of a subcritical assembly, we first made some experiments with the assembly on the parameters of the uranium graphite lattice with natural uranium rods, for which experimental data has been published in the literature (Ref. [1]). Later on, using assemblies of different dimensions we studied the lattice parameters of a reactor of the Beloyarskii GRES described in Ref. [2].

Description of Reactor

The experiments were made on a uranium graphite reactor working at zero power. We studied lattices with the spacing of 200 x 200 mm. The graphite core was 2.2 m in height and 4 m in diameter. The core contained vertical holes spaced 200 x 200 mm for the introduction of uranium elements. The diameter of the holes could be varied from 44 to 75 mm to fit the diameter of the uranium elements. The reactor had upper and lower reflectors 60 cm thick as well as the side reflector, the dimensions of which could be changed to suit the composition of the active zone. The inner and outer parts of the active zone of the reactor were different. The outer part of the active zone always contained 2% enriched uranium rods, while the inner part contained the subcritical assembly, which was part of the reactor lattice under investigation. The natural and 2% enriched uranium rods were 1 m long.

In measuring the parameters of the Beloyarskii GRES lattice, one-meter-long sections of ring-type fuel elements containing 1.2% enriched uranium were placed in the subcritical assembly, thus giving a mockup of the real elements. The active tubes in this case consisted of an assembly of six such elements located around a central tube.

The Beloyarskii GRES reactor uses evaporating and superheating tubes (Ref. [2]). The water content in the evaporating tubes is ten times greater than in the superheating tubes. In the mockup of the evaporator tubes the central...
**Table 1. Constants of the Critical System Investigated**

<table>
<thead>
<tr>
<th>Number of tubes</th>
<th>Inside part of the active zone (subcritical assembly)</th>
<th>Outside part of active zone* *</th>
</tr>
</thead>
<tbody>
<tr>
<td>44*</td>
<td>ring elements, 1.2% enrichment</td>
<td>75</td>
</tr>
<tr>
<td>21*</td>
<td>the same</td>
<td>52</td>
</tr>
<tr>
<td>13</td>
<td>&quot;</td>
<td>41</td>
</tr>
<tr>
<td>9</td>
<td>&quot;</td>
<td>34</td>
</tr>
<tr>
<td>1</td>
<td>&quot;</td>
<td>11</td>
</tr>
<tr>
<td>25</td>
<td>35 mm diameter natural uranium rod</td>
<td>55</td>
</tr>
<tr>
<td>Homogeneous lattice</td>
<td>-</td>
<td>106</td>
</tr>
</tbody>
</table>

* Experiments were made for tubes with and without water. The difference in the number of tubes in the outside zone with and without water is less than 1%.

* * In the 44 tube assembly the rods in the outside zone were 120 cm long, in all other cases 100 cm.

Channel of the fuel elements and the central tube of the assembly were filled with water, while in the mockup of the superheating tubes, no water was used.

Table 1 gives the number of tubes in the inner and outer parts of the active zone, constituting the critical system.

**Selection of Assembly Dimensions**

It is possible to measure the physical parameters of a lattice with the subcritical assembly only in case the dimensions of the assembly are such that the neutron spectrum in the central part of the assembly is that which is characteristic of the lattice being studied. We know that a neutron spectrum of this sort has been established in the center of the assembly if the cadmium ratio or the relative density of thermal and resonance neutrons in the central part of the assembly does not change if the dimensions of the assembly are increased. In this case the dimensions of the assembly are large enough to measure the lattice parameters.

The necessary dimensions of the assembly may also be chosen on the basis of measurements of the physical constants of the lattice ($\phi, \mu, \theta$) or by direct measurement of the neutron spectrum in the center of the assembly by finding the dimension at which the parameters stop changing as the dimensions of the assembly are increased.

Fig. 1 shows the active zone of a reactor containing 13 and 25 natural uranium tube assemblies, and Fig. 2 shows the cadmium ratios for these same assemblies.

It is clear from Fig. 2 that in the central part of both assemblies the densities of thermal and resonance neutrons are exactly the same since the cadmium ratios in the center of the reactor are identical for both assembly dimensions. This shows that in the center of the assembly the relationship established between the thermal and resonance neutrons is characteristic of the corresponding homogeneous lattice.

The spectrum of thermal neutrons in the center of the assembly as a function of dimensions was investigated by measuring the temperature of the neutron gas. These measurements were made by transmission, Ref. [3], by filters, Ref. [4, 5] and by direct measurement of the thermal neutron spectra with the monochromator described in Ref. [6]. In the first case the neutron beam was taken out of the center of the reactor through a vertical test hole and passed through boron filters. The test hole was formed by taking the uranium rod out of the central lattice cell. The measurement of the neutron gas temperature with filters (gold was used for the indicators and filters) was made in the central cell of the reactor. In the direct measurements of the spectra a neutron beam from the center of the reactor was taken out through a horizontal test hole. The spectrum was measured averaged over the cell. The temperature of the neutron gas was found by the method of least squares from the experimentally determined spectra.