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Boosters taking the two-cascade structure with cascade
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without it. In all cases, in order to benefit significantly
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neutron coupling is major at this process. The factor of
property of unidirectional conduction of cascade
Lowering of requirements to the accelerator
power, as it was shown in papers [7, 8], can be reached
on the basis of using two-cascade blankets with cascade
one-way neutron coupling, i.e. using diode blankets. From
the mentioned papers there follows that the
property of unidirectional conduction of cascade neutron coupling is major at this process. The factor of
blankets two-cascade structure brings no advantages
without it. In all cases, in order to benefit significantly
by going over to a two-cascade structure of blankets,
there is necessary to provide a high (on 100-1000 - fold
level) relation of factors of cascade coupling.
Physically, the most efficient method to create a
cascade diode coupling was proposed at VNIIEF [9].
This method is based on application of threshold fissile
material - neptunium-237 in one of cascades and
separation of cascades by a neutron moderator layer.
Initially, the method was oriented to applications in
the field of pulsed boosters serving as neutron irradiators. Development of these devices faces the difficulties,
similar to those in case of electronuclear power
facilities, as the generation of neutron pulses with short
duration in boosters necessary for irradiating experiments usually needs very powerful pulsed
electron accelerators. Basing on the mentioned proposal, at VNIIEF in Russia and in Sandia National
Laboratories in the USA there were developed designs of
irradiating boosters with unique parameters [10, 11].
Boosters taking the two-cascade structure with cascade
diode coupling allowed (according to calculations) to
decrease abruptly neutron pulses duration (at invariable
accelerator power).

Basing on the proposals and analysis of papers
[9, 12], in the early eighties there was developed in
VNIIEF a design of booster-reactor "Kaskad" (BR-K)
with the internal core made of 237Np + Ga alloy and
the external core – of uranium-molybdenum alloy [10].
It was supposed that BR-K would operate combined
with high-current electron accelerator LIU-30 [13]
which is to provide the core of neptunium-237 with
1·1015 primary neutrons per 20-100 ns long pulse. In
the design of BR-K there are taken into account to a
maximum extent the requirements conditioned by the
desire to get possibly highest values of neutron fluence and gamma-radiation dose per pulse at points of
samples irradiation, larger volume of irradiation cavities
and to make easier the access to the places of samples
irradiation. The selection of cylindrical booster-reactor
geometry, horizontal orientation of its axis, degree of
uranium enrichment in the external core, volume and
configuration of internal cavity was governed by the
above requirements.

Basic elements of BR-K design are presented on
Fig.1. BR-K has a cylindrical shape with coaxial
arrangement of internal and external cores, layer of
tungsten, accelerator target and cavity for irradiation.
The axis direction is horizontal.

The internal core (core-1) is made of alloy of
237Np with 9% of gallium by mass. The diameter and
length of core 1 are correspondingly equal to 23 and
~25 cm. The full mass of alloy in core 1 constitutes
120-130 kg. Core 1 is collected of cylindrical
components 0-6, 6-16 and 16-23 cm in diameter and
~8 cm long.

The external core (core 2) is made of alloy of
uranium (36% -enrichment by 235U) and 9% of
molybdenum by mass; it has a form of a hollow cylinder
105 cm long with a maximum external diameter
~70 cm, diameter and length of the channel for
irradiation is equal to 36,5 cm (the dimensions are
specified by fuel. The total mass of alloy in core 2 is
equal to ~2400 kg.

The space between core 1 and core 2 is filled
with tungsten (to be more precise - with the alloy of
tungsten, nickel and copper; mass content: tungsten -
95%, nickel - 3%, copper - 2%) of 18,0 g/cm3 density.
It should be mentioned, that all known papers on diode
two-cascade systems refer to calculation-theoretical or
design ones. The experiments on diode systems have
been conducted nowhere till now. Theoretical
conclusions on diode cascade systems properties are to
be proved experimentally.

**BR-K VIEW IN AXIAL SECTION [10]**

Performance of this type experiments is one of
main tasks of the proposed investigations. The planned
experiments will aim, first of all, at affirmation of
reality of information on strong suppression of one of

cascade neutron coupling factors due to neptunium-237 employment as well as to the fact that strong suppression of one of coupling factors really raises electronuclear facility efficiency.

Fig. 1.

1 - reflector of neutrons; 2 - regulating block of core 2 (RB-2); 3 - mobile block of core 2 (MB-2); 4 - emergency block (EB); 5 - immobile block of core 2 (IB-2); 6 - regulating block of core 1 (RB-1); 7 - stop-block (SB) and pulse block (PB-2); 8 - channel for bremsstrahlung run; 9 - LiH-type neutron moderator; 10 - mobile block of core 1 (MB-1); 11 - pulse block of core 1 (PB-1); 12 - immobile block of core 1 (IB-1); 13 - tungsten massif; 14 - container for irradiated samples.

At present at our institute there are planned investigations of physics blanket neptunium cascade model. As a primary neutron generator it is supposed to use a target of the electron linear accelerator LU-50 [14], operating at VNIIEF; the neutron yield from this target can be brought up to \(10^{14}\) n/sec. The accelerator is designed to operate continuously in the mode of generation of neutron pulses with a different amplitude and repetition frequency up to 2400 Hz.

As a result of a large number of calculations conducted under Monte-Carlo programs there were grounded the most rational configurations of diode two-cascade blanket models, suitable for carrying out experiments under the Project. There were selected blanket configurations using comparatively small fissile materials amounts and known to satisfy nuclear safety requirements without taking special safety measures (Fig.2).

Besides the above-mentioned arguments, the expediency of low \(k_{\text{eff}}\) value assemblies employment in the planned experiments is also proved by the fact that exactly on such assemblies type there is possible to compare directly data of experiment and numerical calculation. As it is shown in paper [8], the direct calculation of \(k_{\text{eff}}\) and total numbers of diode blanket fissions with the help of modern Monte-Carlo programs, in the case of blankets with large value of \(k_{\text{eff}} (>0.9)\), is extremely difficult. In this case, \(k_{\text{eff}}\) and total fission numbers are calculated with the aid of theoretical formula of relationship between these magnitudes and easily calculated factors of neutron multiplication in cascades \(k_{\text{eff1}}, k_{\text{eff2}}\) and factors of cascade neutron coupling \(k_{12}, k_{21}\).

Model assemblies with low \(k_{\text{eff}}\) planned for executing experiments

Diagrams of model assemblies with \(k_{\text{eff}}=0.53\)

Neutron source

<table>
<thead>
<tr>
<th>Neutron source</th>
<th>Neptunium-237</th>
<th>Polyethylene</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho = 20.45)</td>
<td>(\rho = 0.92)</td>
<td>(\rho = 18.7 \text{ g/cm}^3)</td>
<td></td>
</tr>
<tr>
<td>(M = 2 \text{ kg})</td>
<td></td>
<td>(M = 18.0 \text{ kg})</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(235\text{U} - 90%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(238\text{U} - 10%)</td>
<td></td>
</tr>
</tbody>
</table>

Neutron source

<table>
<thead>
<tr>
<th>Neutron source</th>
<th>Neptunium-237</th>
<th>Vacuum</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho = 20.45)</td>
<td></td>
<td>(\rho = 18.7 \text{ g/cm}^3)</td>
<td></td>
</tr>
<tr>
<td>(M = 2 \text{ kg})</td>
<td></td>
<td>(M = 33.6 \text{ kg})</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(235\text{U} - 90%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(238\text{U} - 10%)</td>
<td></td>
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</tbody>
</table>

Neutron source

<table>
<thead>
<tr>
<th>Neutron source</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho = 18.7 \text{ g/cm}^3)</td>
<td></td>
</tr>
<tr>
<td>(M = 7.28 \text{ kg})</td>
<td></td>
</tr>
<tr>
<td>(235\text{U} - 90%)</td>
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<tr>
<td>(238\text{U} - 10%)</td>
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</tbody>
</table>

In the experiments there will be measured the factors of section neutron coupling \(k_{12}, k_{21}\) and, what is more important, absolute spatial distributions of fissions density in sections allowing to determine total numbers of fissions in cascades and assemblies in the aggregate, with normalization per one source neutron. The data of measurements on two-cascade assemblies will be compared to similar measurements on one-cascade assemblies. At this process, an important requirement is maintenance of equality of \(k_{\text{eff}}\) of assemblies. Removal of intermediate layer diminishes the magnitude of cascade coupling factors relation, but, however, in this case the assembly also remains a two-cascade diode one. The intermediate layer removal may be
compensated through a change of uranium layer thickness or by an external reflector.

The computations testify to acceptability of these assemblies with low $k_{\text{eff}}$ values as a base for conducting the planned experiments. The difference in efficiencies of one-cascade and diode two-cascade blankets is not large in this case, but, however, it is quite enough to be noted in the experiment. The aforesaid is proved by data for the models with $k_{\text{eff}} = 0.53$. Total fission numbers in these blanket models, referred to one neutron of a central source with a fission spectrum, are equal to 1.26; 0.803 and 0.633. This means that efficiency of the two-cascade diode blanket models is 1.99 and 1.27 times higher than that of the one-cascade blanket (cascade coupling factors $k_{11}, k_{12}$ in the upper assembly and the following one equal, relatively: 0.657; 0.0078 and 0.337; 0.017).

In spite of small masses of used fissile materials and, correspondingly, low levels of keff neutron multiplying factors, these blanket configurations provide a possibility for precise experiment recording of quantitative indexes of these models of diode two-cascade blanket as compared to common blankets indexes. As expected, the experimentally obtained data will directly prove the rightness of theoretical knowledge on diode blankets advantages and will serve a reliable benchmark base for correcting calculation methods.

REFERENCES