THE SM CRITICAL ASSEMBLY
USED TO STUDY CHARACTERISTICS
OF NEUTRON DETECTOR SCREENS
OF THE ITER FUSION REACTOR


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ITER power monitoring is expected to perform using a neutron flux detector that applies threshold fission chambers with $^{238}\text{U}$ radiator. The monitoring detectors are developed by the experts from the Russian Federation. The detector parameters should be stable during its whole operational lifetime. To reduce the rates of nuclear reactions on thermal neutrons in a threshold fission chamber radiator it is intended to use protective absorbing shields made of boron carbide.

The shields should prevent background signal increment due to fission of $^{239}\text{Pu}$ that will be accumulated in the threshold fission chamber radiator during their long-term operation in the neutron flux.
To verify the calculation data on measuring the factor of neutron thermal flux density attenuation by the protective shields experiments are performed at the SM-2 critical assembly. The factors of attenuation of different energy spectrum neutron flux density by the absorbing shields made of natural isotopic composition boron carbide have been measured applying various independent methods:

– using foils (activation tracers) made of $^{235}$U;
– using ionization fission chamber with $^{235}$U radiator.
Test Subject Matter

The subject matter was two prototype models of the protective shields of similar design and different neutron absorber thickness: 7 mm for shield #1 and 10 mm for shield #2. The shield design is two coaxial cylinder steel shrouds with a gap between them filled with vibropacked boron carbide powder. Boron carbide was also placed into the shield end covers (removable and fixed).
Protective shield #1. Assembly drawing fragment
For each shield the following factors have been measured:

1. The factor of thermal neutron flux density attenuation by the ionization fission chamber counting rate on the SM-2 critical assembly experimental tank wall (thermal neutron spectrum).

2. The factor of neutron flux density attenuation and its distribution by height using the activation tracers in the SM-2 critical assembly central cavity with displacing water from it (epithermal neutron spectrum).
SM-2 Critical Assembly Description

The critical assembly is a physical model of the SM high-flux research reactor. The geometry and material composition of the critical assembly with reference to the core and reflector correspond to the reactor ones. The critical assembly is accommodated in the experimental tank filled with water. Upon experiment completion water is drained off the tank.

The core cross-section is a 420×420 mm square (6×6 cells spaced at 70 mm along the square grid). Four central cells are used to accommodate the central moderating cavity (CMC) – neutron trap, four corner cells – for shim rods. All in all, up to 28 FAs can be installed in the core (when inserting shim rod clusters in the core during the experiment the total number of the FAs can be 32). Four safety rods are placed in the central moderating cavity corners.
SM-2 critical assembly cross-section
Milestones and Conditions Required for Conducting Experiments

To determine the protective absorbing shield attenuation factors under various conditions by the neutron energy spectrum two regions to accommodate the protective shields in the critical assembly experimental tank are selected:

- in the region where the standard ionization chambers of the critical assembly control system are located (on the experimental tank inner wall) – thermal neutron spectrum;
- in the critical assembly central channel with water being displaced from the channel – epithermal neutron energy spectrum.
Diagram of the channel arrangement in the experimental tank and its cross-section with protective shield #2 and ionization fission chamber (IFCh), with protective shield #1 and IFCh, with IFCh (downwards)
Cross-section of the critical assembly central moderating cavity when protective shield #2 is installed with a cover (a) and with no cover (b):

1 – beryllium insert with a safety rod channel; 2 – aluminium channel; 3 – protective shield; 4 – aluminium plate; 5 – IFCh; 6 – activation tracer.
The following measurements have been performed:

1. Signal of IFCh when it is placed near the experimental tank wall at the SM critical assembly constant power.

2. Signal of IFCh when it is accommodated in the central channel at the SM critical assembly constant power.

3. Neutron shields equipped with activation tracers have been irradiated in the central channel at the critical assembly fixed power.
# Measurement Results

The results of measuring the thermal neutron flux density factor of attenuation by protective shields on the experimental tank wall

<table>
<thead>
<tr>
<th>Measure No.</th>
<th>Ionization fission chamber with no shield</th>
<th>Ionization fission chamber in shield No.1</th>
<th>Ionization fission chamber in shield No.2</th>
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<tr>
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<td>count time, s</td>
<td>count, pulses</td>
<td>count rate, pulses/s</td>
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<tr>
<td>Ionization fission chamber count rate attenuation factor</td>
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<td>2540</td>
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</table>
The results of the measurements with tracers

The activity of tracers after irradiation in the SM-2 critical assembly was measured using a unit for measuring the fuel rod activity and tracers with two similar channels – main and monitoring channels.
Neutron flux attenuation factor distribution by height

1. Protective shield #1 in the critical assembly CMC,
2. Protective shield #2 in the critical assembly CMC,
3. Protective shield #2 with no cover in the critical assembly CMC
Conclusions

1. Shield #2 by 1.3 times more efficiently attenuates the neutron flux under the thermal spectrum.

2. Under the epithermal neutron spectrum the fission reaction attenuation factor in the activation tracers for shield #1 is 9.1; for shield #2 – 10.8; for shield #2 with no cover – 9.6.

3. Based on the results of the shielded ionization chamber counting rate measurement in the critical assembly central channel (epithermal neutron spectrum) it was revealed that the ionization fission chamber counting rate in protective shield No.2 is by 1.21 times lower at the same critical assembly power as compared to shield No.1. A close ratio (1.18) was obtained for the tracer activity.

4. The attenuation factors for the protective shields measured by the fission rate under thermal and epithermal neutron spectra differ by more than two orders.
Thank you for your attention!