NEUTRON FLUX SPECTRA AND RADIATION DAMAGE PARAMETERS FOR THE RUSSIAN BOR-60 AND SM-2 REACTORS - A. V. Karasiov (D. V. Efremov Scientific Research Institute of Electrophysical Apparatus, St. Petersburg, Russia) and L. R. Greenwood (Pacific Northwest Laboratory)[a]

OBJECTIVE

To compare neutron irradiation conditions in Russian reactors and similar US facilities.

SUMMARY

Neutron fluence and spectral information and calculated radiation damage parameters are presented for the BOR-60 (Fast Experimental Reactor - 60 MW) and SM-2 reactors in Russia. Their neutron exposure characteristics are comparable with those of the Experimental Breeder Reactor (EBR-II), the Fast Flux Test Facility (FFTF), and the High Flux Isotope Reactor (HFIR) in the United States.

PROGRESS AND STATUS

Andrei Karasiov recently visited the Pacific Northwest Laboratory (PNL) as part of the Young Scientist's Exchange agreement between Russia and the U. S. Department of Energy, Office of Fusion Energy. The purpose of the visit was to perform radiation damage calculations for the BOR-60 (fast reactor) and SM-2 (mixed-spectrum reactor) facilities in Russia; the calculations were based on neutron flux and spectral information provided by the reactor facility operations.[1,2] The reactors are at Dimitrovgrad, Russia, and are operated by the Scientific Research Institute of Investigation of Atomic Reactors (SRIIAR).

Since the closure of the FFTF and EBR-II fast research reactors in the United States, reactors in other countries have been evaluated as potential sites for fusion materials irradiation research programs.

The SM-2 reactor, which began operation in 1961, has a high-flux trap in the center to produce tranuranic elements and other radioisotopes, as shown in figures 1 and 2.[1] The reactor core is 42-cm square by 35-cm high, and has a total volume of 50 L. The light-water cooled reactor has a beryllium reflector, similar to that of HFIR, and operates on 90% enriched uranium oxide fuel. Experiments may be placed in channels with either water or gas cooling, and operating temperatures are in the range of 100 to 800°C. The reactor normally operates on a 40-to-45 day cycle with 5 to 6 days for refueling. The facility thus is available on about 240 full-power days per year. The central flux trap has a maximum thermal neutron flux of about $5x10^{15}$ n/cm^2-s; the fast flux (>0.1 MeV) is about $2x10^{15}$ n/cm^2-s. However, other positions are of interest for fusion materials experiments (see figure 2). Experimental samples may be placed in special fuel assemblies, 20 channels in the beryllium, or 5 channels in the reflector. Some of these channels have temperature control and are instrumented for materials testing. Neutron flux and spectral data were available from recent experiments in the active zone (AZ) of the reactor core (SM-2 AZ) and in channel 2 (SM-2 C2). Sample capsules for irradiation in the AZ position are 8 to 9 mm in diameter, and those in the C2 position are 52 mm.

The BOR-60 facility is a fast, sodium-cooled reactor operating on either 90% enriched uranium oxide or mixtures of up to 40% plutonium oxide. The facility started operation in 1969 and was designed to test

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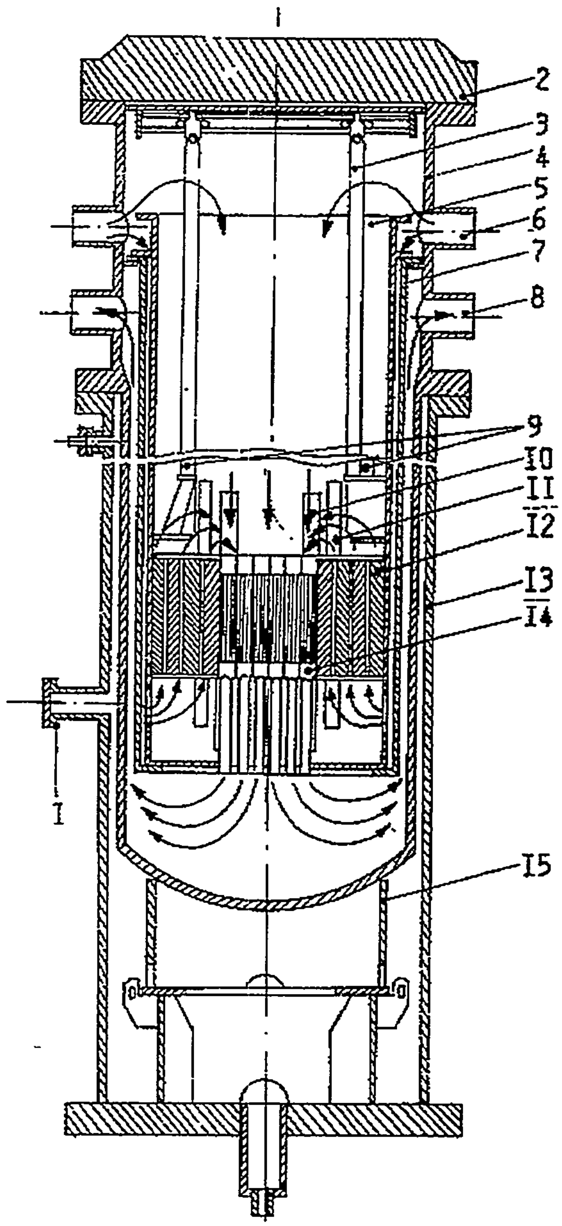

Figure 1 The SM-2 reactor. 1-horizontal channel; 2-cover; 3-fuel loader; 4-reactor vessel; 5-separator; 6,8-input and output tubes; 7-shield; 9-fuel savers; 10,11-compensator tubes; 12-Be shield; 13-pressure vessel; 14-core (fuel); 15-bottom.

fuel elements, structural materials, and fast-reactor safety issues. The cylindrical core, which measures 40.4 cm in diameter by 40 cm high, is surrounded by a stainless steel reflector and a depleted uranium-oxide breeder region, as shown in figures 3 and 4. The hexagonal assemblies have a minimum width of 4.4 cm. Nominal operating temperatures are in the range from 340 to 1000°C, and radiation heating is about 4 W/g. Experimental assemblies can be placed in most of the positions shown in figure 4. Some positions are temperature controled and are instrumented for materials experiments. Horizontal and vertical experimental channels are also located in the bulk of the biological radial blanket. The maximum

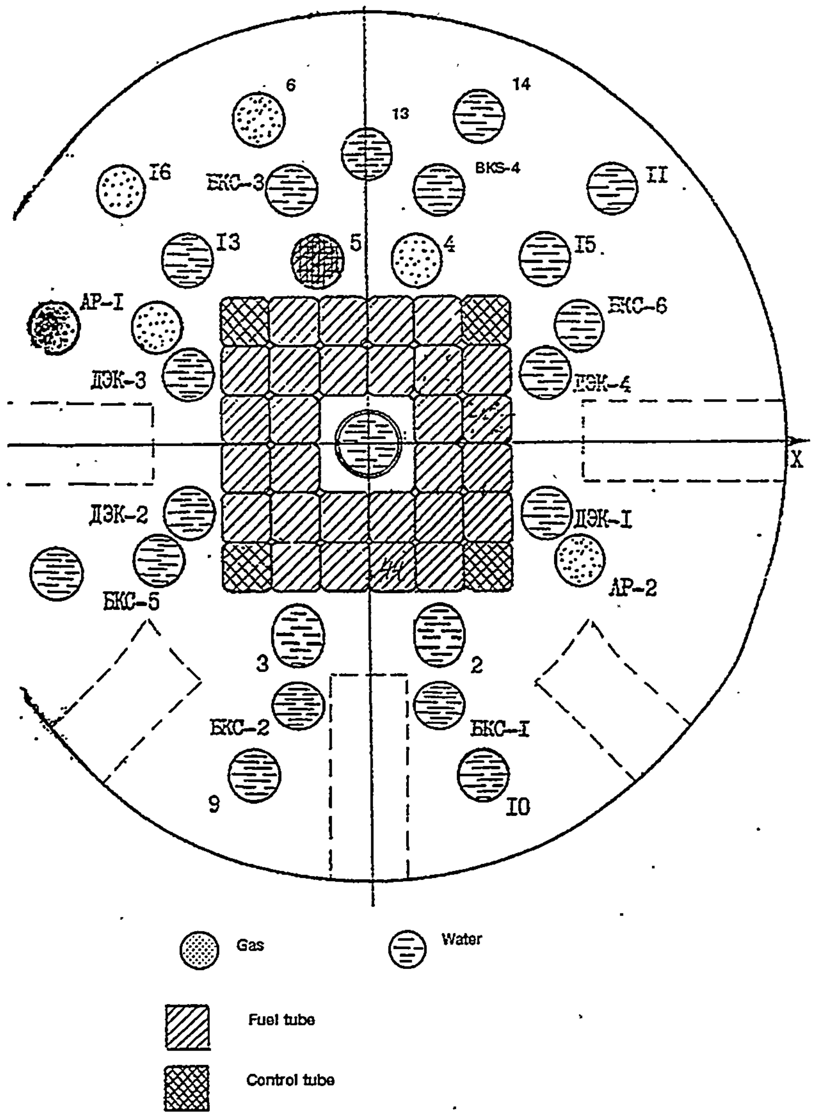

Figure 2 Core diagram of the SM-2 reactor. Fuel elements are shown by diagonal lines and compensators (CO) by cross hatching. Horizontal channels are filled either with water (dashes) or gas (dots).

neutron flux in the horizontal channels is 1.2×10^{14} n/cm^2-s and in the vertical channels is 3.8×10^{13} n/cm^2-s.

Characteristics of the various reactors are compared in Table 1. Quoted neutron flux levels are for the reactor centerline positions. Flux values for the U. S. reactors were taken from recent neutron dosimetry experiments.[3,4,5] Figures 5 and 6, respectively, compare the neutron flux spectra for fast reactors and mixed spectrum reactors. The two Russian reactors are quite comparable to the corresponding U. S. facilities. The HFIR reactor can operate at 100 MW; however, operations are currently restricted to 85 MW to limit radiation damage to reactor components. The FFTF facility originally operated at 400 MW; however, in its last years before closure it operated at only 295 MW to save operating costs. BOR-60 can

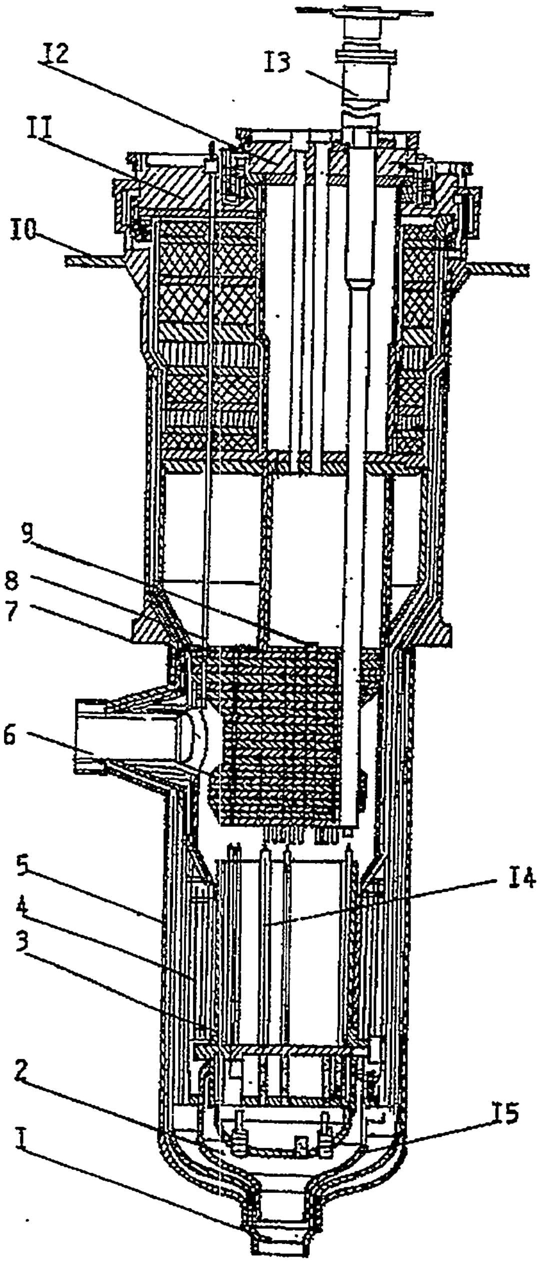

Figure 3 The BOR-60 reactor. 1,6-input and output tubes; 2-input camera; 3-basket; 4-thermal neutron shields; 5-pressure vessel; 7,10-flanges; 8-thermocouples; 9-control rod; 11,12-shields; 13-loading channel; 14-fuel elements; 15-bottom vessel.

operate at 60 MW but normally operates at 40 to 55 MW.

Radiation damage calculations for all of the reactors were performed with the SPECTER computer code.[6] Displacement damage and helium production rates for pure iron are also listed on Table 1. The high thermal neutron flux in SM-2 and HFIR mean that multi-stage reactions in nickel and copper will produce much higher levels of hydrogen and helium as well as some additional displacements per atom (dpa) damage at high neutron fluences.

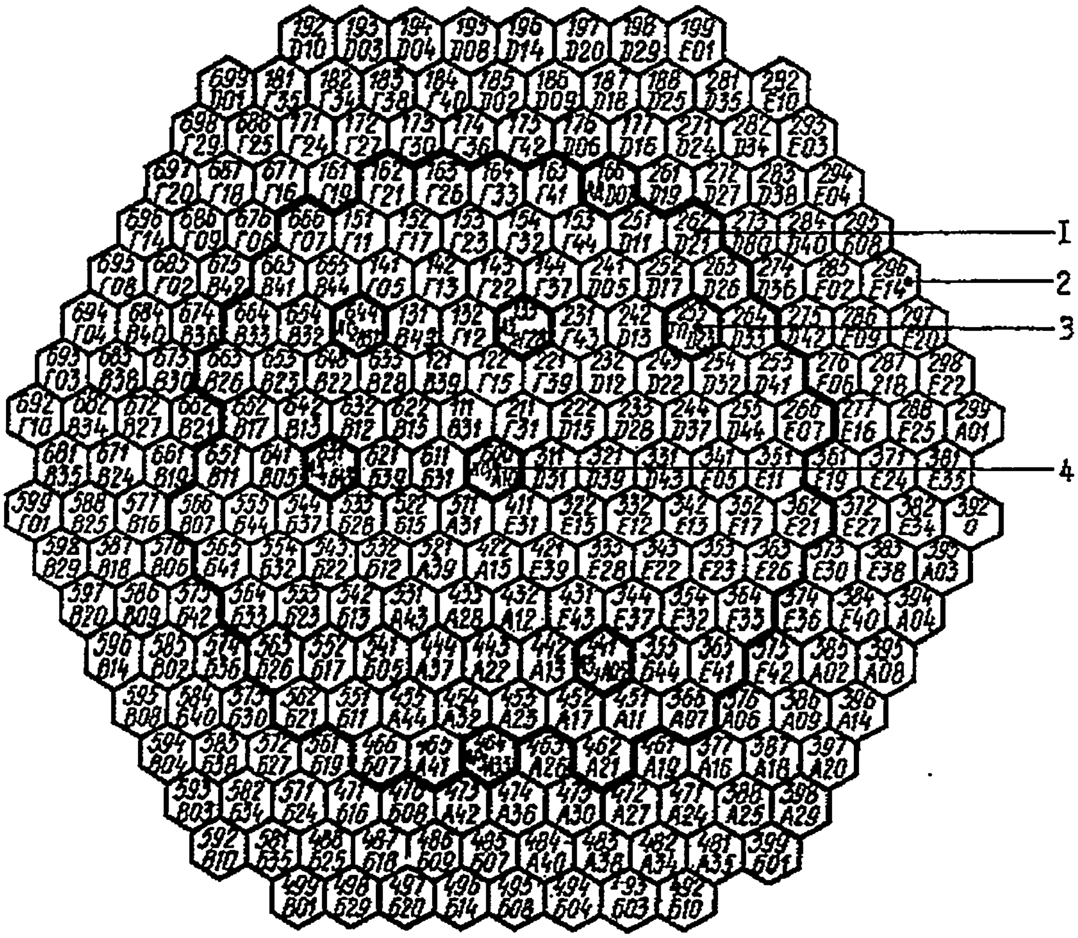

Figure 4 Core diagram of the BOR-60 reactor. 1 - fuel assembly, 2 - radial blanket assembly, 3 - thermometric channel, and 4 - control rod.

CONCLUSIONS

The Russian reactors are comparable to the American reactors in terms of neutron flux and radiation damage. The BOR-60 and SM-2 facilities are available for suitable radiation damage experiments.

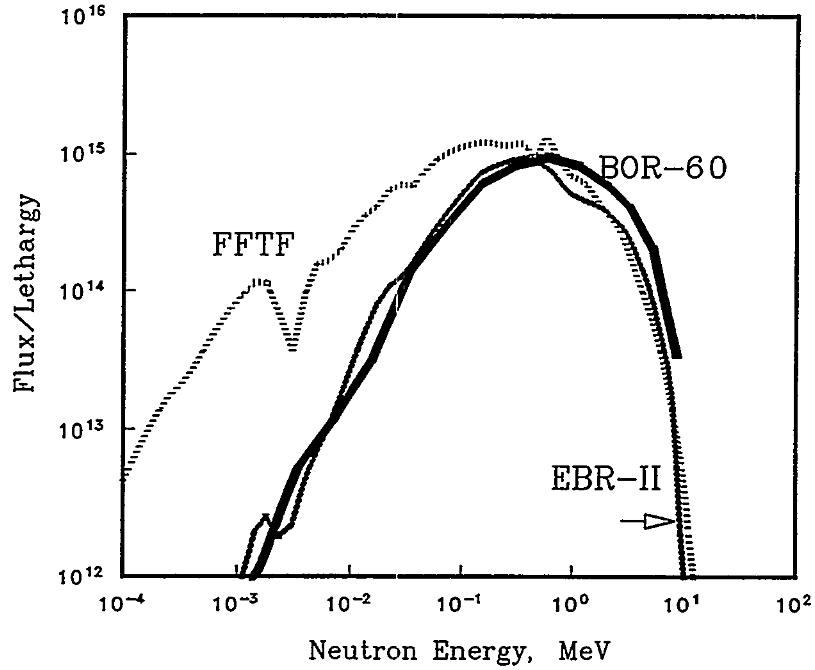

Figure 5 Comparison of centerline neutron spectra for the fast reactors BOR-60, EBR-II, and FFTF.

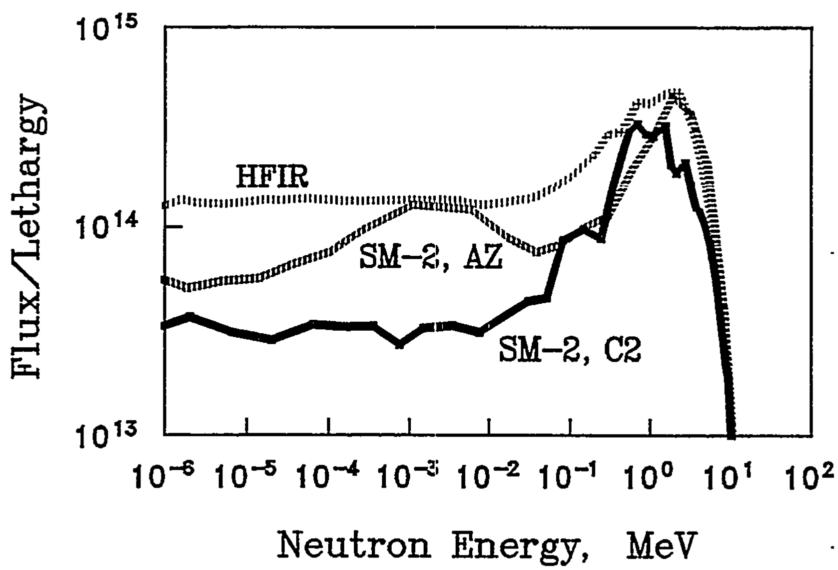

Figure 6 Comparison of midplane neutron spectra for the mixed-spectrum reactors SM-2, at the AZ and channel 2 positions, and HFIR.

Table 1 - Comparison of Russian and U. S. Reactors

	SM-2 AZ	HFIR	BOR-60	EBR-II	FFTF
Thermal Power	100	85[a]	55	62.5	295[b]
Neutron Flux, $x10^{15}$ n/cm^2-s:					
Total	3.5	4.0	2.0	2.6	5.6
Thermal (<0.5 eV)	1.5	1.6	-	-	-
0.5 eV to 0.1 MeV	1.0	1.3	0.22	0.45	1.9
> 0.1 MeV	1.0	1.1	1.8	2.3	3.1
> 1 MeV	0.6	0.6	0.5	0.6	0.6
dpa/y (Fe)	27	26	24	33	34
He,appm/y (Fe)	15	9.3	12	3.5	3.5

[a]HFIR is capable of operation at 100 MW.
[b]FFTF is capable of operation at 400 MW.

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