NEUTRON SOURCES

The IBR-2 Pulsed Reactor

In the period from 1 October 1990 to 1 October 1991 the IBR-2 has operated for 2569 hours (10 cycles) to feed the physical experiments staged on 11 beam-lines.

The IBR-2 performance in the reported period is detailed in Table 1.

Beginning from October 1987 the IBR-2 operates with the new moving reflector, MR-2 (PO-2), in place of the first moving reflector, MR-1 (PO-1), having run 13211 hours since the reactor startup. The MR-2 design service time is 18000 hours. Its operating age by 1 October 1991 amounted to 12166 hours. The maximum fluence the MR-2 blade is built to sustain is 6.7×10^{25} n/m^2. By 1 October 1991 it was 4.38×10^{25} n/m^2.

The annual program of measurements on the IBR-2 reactivity power effect has been successfully performed. The details are reported in the following sections.

Table 1 The characteristics of the IBR-2 reactor operation in the reported period

1.	Average thermal power	2 MW
2.	Peak power in pulse	1500 MW
3.	Half width of fast neutron pulse	215 μsec
4	Thermal neutron flux density from surface	
	- of flat moderator,	
	time averaged,	5×10^{12} n/(cm^{2}sec)
	same at burst maximum	4×10^{15}n/(cm^{2}sec)
	- of grooved moderator,	
	at burst maximum	10^{16}n/(cm^{2}sec)
5.	Pulse repetition rate	5 p.p.s.

IBR-2 Investigations. Main results

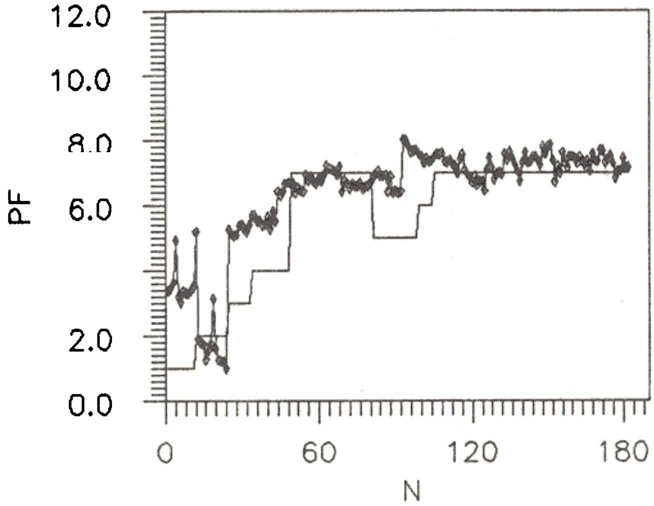
These regular investigations have the aim of providing experimental confirmation of the stable and safe operation of the reactor. The collected data are used to estimate reliability of the whole reactor and of its components.

Monitoring and diagnostics of the reactor

Actually, the parameters of the reactor are stable on average. At the same time the extent of reactor noise varies during operation and it can be taken as the indirect parameter of the current reactor state control. In the IBR-2 reactor this control is executed by two tightly bound systems, one for monitoring and the second for diagnostics of the reactor state.

Noises are being measured and the data collected during every reactor cycle to yield main statistical characteristics of power pulses, reactivity and moving reflector fluctuations. The

Fig.1.1. The clustering time diagram (the step-like diagram) and power fluctuations during the reactor performance with the MR-2 moving reflector.



noise spectrum analysis by the pattern recognition method helps to reveal anomalous spectral structures. During the reported 1991 year the IBR-2 operated in the same stable regime as in 1990. Changes in reactor noise extent are illustrated in Fig.1.1 through power fluctuation standard deviations (SD) and cluster time characteristics. The noise extent transition seen at the outlet of this curve reflects vibration instability of the MR-2 in the initial period of operation. Then the curve shows stabilization and further perfect operation of the reflector.

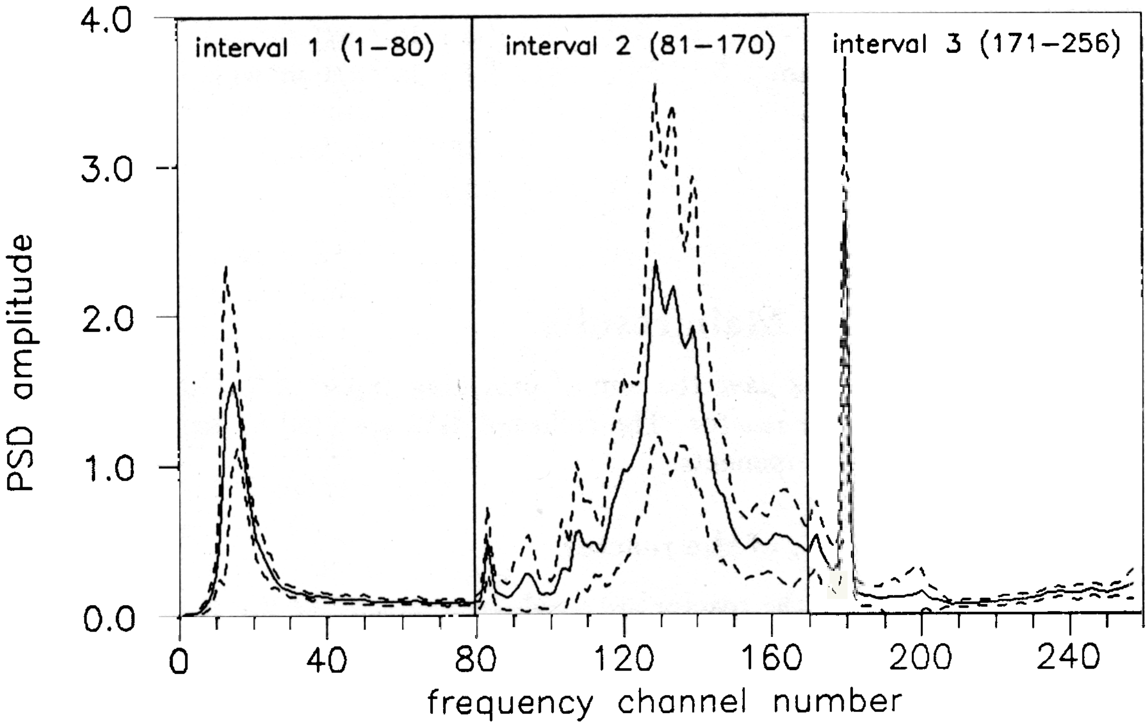


Fig.1.2. The average power spectral density representing the 7th (see Fig.1.1) cluster center (solid line) with ± standard deviations (dashed lines) in every frequency channel. The splitting of the full frequency interval into three is shown.

Another characteristic of the noise extent is the averaged spectrum, the "cluster 7" center shown in Fig.1.2 by the solid line. The dashed lines represent standard deviations in each of the frequency windows. The total frequency interval is divided into three, low, medium and high frequency, windows. These windows can be processed separately to extract detailed information about changes in reactor performance. For example, thus obtained information evidences, that the statistical characteristics of the new power fluctuation source, first observed in 1989, did not change in the reported period (the frequency from 1 to 1.5 Hz in the window ([80, 170], Fig.1.2). This source appears at an average power of 0.9 MW and its intensity grows by 1.2% (in SD units) with the increase of power to 2 MW. Its connection has been established with the vibrations of the moving reflector, MR, or to be more exact, with the vibrations of its mounting hardware and helium jacket.

Additionally, a narrow region ([175-185] window in Fig.1.2) with the peak, which reflects the moving reflector behaviour, was analysed. This peak is responsible for the appearance of two subclusters (the reactor substates). A cyclic transition from one to the other is observed with the time of occupation of each substate being no shorter than a complete two-week cycle. This observation can be explained by the fact that the vibrations of the moving reflector depend on its startup conditions. The reactivity variation corresponding to this transition is on the level of only $6 \times 10^{-7} \Delta$ K/K and thus influences neither the operation characteristics nor safety of the reactor.

The "noise pattern" of the IBR-2 operation in the reported period gives evidence of stability of the fluctuations due to reactor and modulator hardware and shows no tendency towards their aggravation or degradation. The noise component due to the cooling system remains unchanged too.

In the reported period measurements on the sensitivity of the diagnostics' system have been undertaken. This diagnostics system based on the pattern recognition method has been shown to be capable of extracting anomalous fluctuations on the level of about $10^{-7} \Delta$ K/K.

Operations

The annual measurement of the dynamical characteristics of the IBR-2 reactor was performed during the scheduled reactor cycle in May, 1991. The mean reactor power was 2 MW, the sodium circulation flow rate 90 m^3/h. The prompt power was modulated with reactivity adjustment rod (AR). The swing of AR displacements was 9 steps (it is about 15 mm). This swing corresponds to about 10% power relative variation. The period of reactivity variation was 0.2 sec, which is 160 times as much as the reactor pulsation period. A specially developed computer treatment has shown that the dynamical parameters of the IBR-2 reactor remained unchanged in the reported period. The stability threshold at a flow rate of 90 m^3/h was estimated to have its earlier value of 8 MW, at a flow rate of 65 m^3/h this estimate is about 2 MW.

IBR-2 Development

The PC-based Control and Monitoring System (PCCMS)

Work has continued to improve the IBR-2 control and monitoring system in a search for higher reliability of control of the reactor state and the state of the maintenance equipment. At the same time the system has been under constant development to increase its information capability on the basis of recent achievements in the field. In 1990 the KFKI (Budapest, Hungary) has advanced a Detailed Plan for the creation of an automated control and monitoring system for the IBR-2 reactor. Soviet experts have approved the Plan and the contract has been signed in June 1990, between the JINR and the firm "Metripleks" for the supply of the first assignment, the IBR-2 technological parameters control system equipment. The delivery of the system components has been accomplished by May 1991 and assembly work has started. There was started test operation of the system in parallel with the existing equipment in the end of 1991. This will help the staff to get adapted to the system and develop new, more convenient programs for the data acquisition and treatment. The whole PCCMS complex comprises, besides the equipment for the technological parameters control, also the equipment of the reactor state control system and electronics to execute necessary logic operations of reactor monitoring and shielding (Fig.1.3).

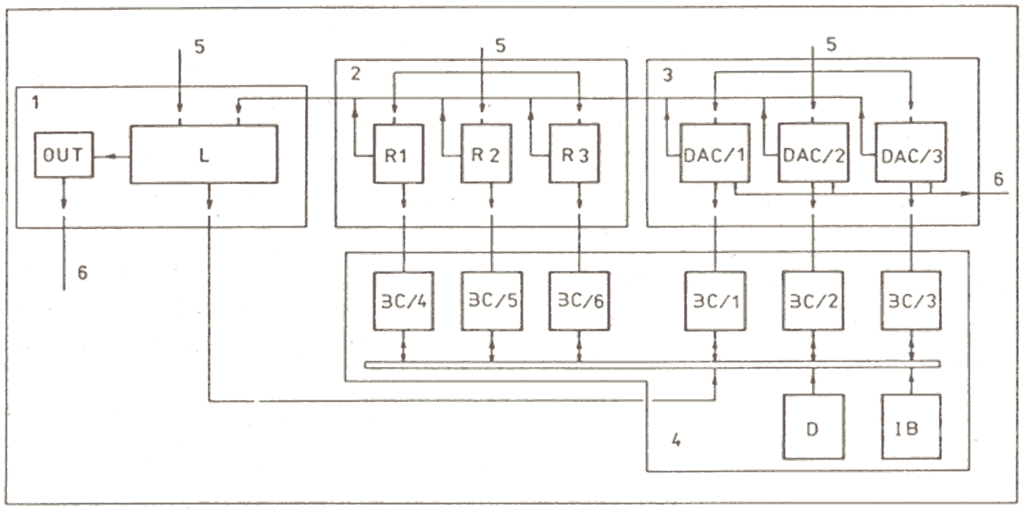


Fig.1.3. Schematical structure of the PCCMS complex of the IBR-2 reactor. 1. Emergency and monitoring signal system. 2. Reactor parameters control system. 3. Technological parameters control system. 4. Information and diagnostics system. 5. Input signals. 6. Output monitoring signals.

The moving reflector, MR-2PM

Work has continued to build the new moving reflector MR-2PM, in which the combination of the heterogeneous structure of nickel rotors with the opposite motion of the main and auxilliary reflector would be realized. In the reported period a considerable number of the new machine components have been manufactured and much attention given to strength control of the rotors.

Solid methane cold moderator

Work on the creation of a solid methane cold moderator (SMCM) for three IBR-2 beamlines (No.4,5,6) is now nearing completion. The schematical view of the moderator is shown in Fig.1.4. The neutron moderation medium is solid methane at 20 K cooled with gaseous helium

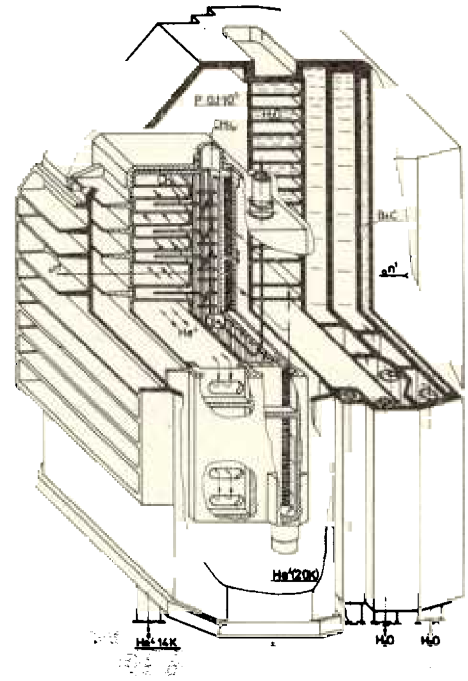


Fig.1.4. The schematical view of the solid methane cold moderator.

at 10-15 K. The expected effect is a tenfold rise of the cold neutron flux in the direction of the three above indicated beam-lines. In the reported period the design work has been completed, the methane-helium chamber, the main component of the moderator, manufactured and vacuum tested. Strain measurements of the chamber were also performed in a wide temperature range up to the working temperature of 20 K. A test rig for the moderator has been commissioned to conduct cold testing of the moderator. The preparatory work for this test is now under way. The new liquid helium production machine was adjusted and started supply of the laboratory physicists with liquid helium.

An instrument to measure solid methane swelling under reactor radiation has been developed. The instrument has guages to help measurement of temperatures and volumes of small methane boxes with flexible walls. This instrument is to be installed near the IBR-2 water moderator by the fall of 1991 and irradiated during two or three scheduled cycles to develop perfect conditions of solid methane cold moderator performance.

Table 2: Characteristics of potential alternatives to the IBR-2

Version	Mean power, MW	Thermal neutron flux, relative, n/sec	Thermal neutron pulse μsec	Background power, %
IBR-2	2	1	300	6
IBR-2,modified				
-PuO_2 fuel	4	1.3	110	6
-U fuel	4	0.8	125	20
-Np fuel	2	0.5	80	1.3–3
IBR-3, new concept of reactor design,				
-U fuel	4	1.3	115	3–4
-Np fuel	0.4	0.06	30–50	1.3–3
LANSCE, ISIS	–	0.01	30	~ 1

Comparative characteristics of potential alternatives to the current IBR-2 reactor

There are plans to start construction of a modified version of the IBR-2 reactor on termination of the first fuel cycle of the PuO_2 core in 1995–1996. Some alternatives were discussed during the year, including those, which offer replacement of plutonium with some other fissile material. The conclusion was made that some of them could ensure shorter pulses (to 50 μsec), some lower background power (2-3%), but none could bring simultaneous improvement of the three main parameters of the neutron source: the flux, the pulse duration, the background power (see Table 2). Preference was given to PuO_2 as the fuel, as it helps to keep high the thermal and cold neutron flux, the most advantageous parameter of the IBR-2 reactor, which is now about 100 times as much as that from the spallation neutron sources.

The Booster IBR-30 + LUE-40

The IBR-30 + LUE-40 has resumed operation on 21 June 1990 after the shutdown for maintenance and machine development. The user running time actually achieved in the reported period was 2243.6 hours (9 cycles). Detailed information on the IBR-30 + LUE-40 operations is given in Table 3. In 1991 the Design Department staff of the LNP have developed a new tantalum target for the IBR-30. The realization of this design would allow more effective use of photoneutrons in the core and uniform distribution of heat release over the fuel elements around the target channel. Schematical views of the now operating tungsten target and of the new tantalum target are given in Figs. 1.5 and 1.6. The new target has been manufactured and is under test now.

Table 3: The parameters of the IBR-30 booster

Electron energy	32 MeV
Electron pulse duration	1.6 μsec
Frequency	100 sec^{-1}
Current in pulse	0.4 A
Average current	64 μA
Average electron beam power	2 kW
Target material	tungsten
Multiplication	200
Neutron pulse duration	4.2 μsec
Mean thermal power	10 kW
Average intensity	3.6×10^{14}n/sec

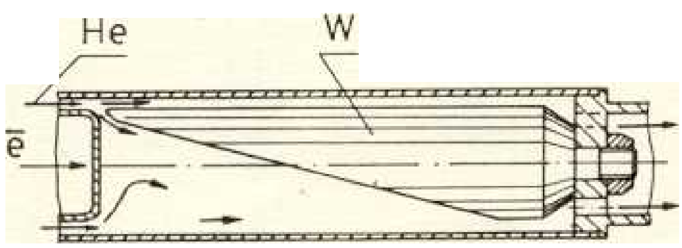


Fig.1.5. The now operational tungsten target

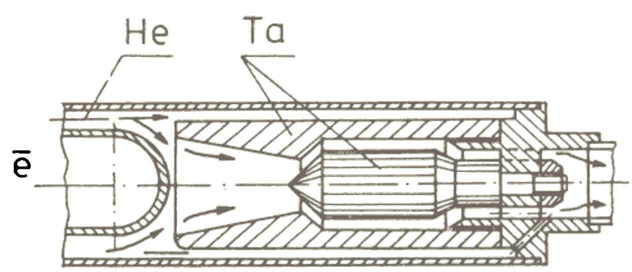


Fig.1.6. The proposed new tantalum target

The High Resolution Neutron Source (HRNS) (A Project)

The high resolution neutron source (HRNS) is proposed to replace the now operating U-Pu booster, IBR-30. It would be a subcritical, highly enriched uranium target on the basis of a powerful linac LUE-100. This source would produce up to 2×10^{15}n/sec with a pulse duration below 1 μsec and a pulse repetition rate up to 200 Hz to serve the nuclear physics experiments by the time-of-flight method. The quality of the source is expected to exceed that of the current IBR-30 booster by two orders of magnitude. Design studies go in two directions, one for the construction of the new LUE-100 electron accelerator and the second for the fabrication of the uranium target.

The Electron Accelerator LUE-100

A conceptual study has been undertaken for the building of the electron accelerator with the parameters: beam power 10 kW, electron energy 150 MeV, electron pulse duration 0.3 μsec, pulse repetition rate 200 Hz. The possibility to actually achieve these parameters has been proved, the construction cost estimated, the development engineering organizations and manufacturer provisionally outlined.

The Multiplying Target Station

Conceptual studies have been undertaken for the construction of the uranium multiplying target to yield ten versions including neutronics and thermohydraulics aspects of construction. The account of this work has been released and the choice made on its basis. Plans and specifications have been drawn of the HRNS with the electron accelerator to 150 MeV and the beam power of 10 kW. The 90%-enriched uranium-molibdenium alloy will be taken as the fissile material. The conversion media are to be natural uranium and mercury. The core will be cooled with a compulsory air flow and the converter by means of the natural convection of mercury. The operational value of the multiplication factor has the upper limit of 0.98. In the stationary mode of the booster the core produces the power of 20 kW, the intensity of 0.9×10^{15}n/sec, the fast pulse duration of 0.45 μsec and the delayed neutrons background of 10%. The target construction allows the reactivity modulation with the help of the four-blade neutron reflector, which rotates at 50 cycles per second. In this mode the power yield would be 50 kW at the maximum value of 0.98 for multiplication factor, the neutron beam intensity 2×10^{15}n/sec at 200 Hz pulse repetition rate, the pulse duration 0.9 μsec, the time averaged delayed neutrons background 11.8%. Plans and specifications include neutronics and thermohydraulics analysis of the core and converter design, the construction details of fuel elements and their assemblies in the core; the principal scheme of the uranium-mercury convertor together with the water-mercury cooling scheme; the construction of the neutron reflectors, moderators and shielding.