2. NEUTRON SOURCES

2.1. THE IBR-2 PULSED REACTOR

In 1998 the program of measurements on the IBR-2 reactor beams continued. The details of IBR-2 operation are summarized in Table 1. As of 21.12.98, the reactor had operated for physical experiment the total of 2043 hours in 8 cycles at the power 1.5 MW.

In accordance with the working plan, preventive maintenance of IBR-2 (PM-98) was conducted in July-September 1998. The main part of PM-98 was repairing of gas vacuum supply lines in the reactor jacket that ensure the necessary level of sodium over the active zone and are most important from the viewpoint of safety.

The stability of IBR-2 operation increased: the number of emergency shutdowns reduced to 10 during the total time of 8 cycles. Comparative data illustrating the IBR-2 stability growth are shown in Figs. 1, 2.

The remaining operation resource of IBR-2 is analyzed and its estimated value as of 1.10.98 is given in Table 2. It is determined by considering the resources of the key elements of the reactor from the viewpoint of operation safety, including

- Movable reflector (PO-2R): mechanical and radiation resources
- Fuel elements, TVELs (burning depth)
- Reactor jacket (radiation and thermocyclic resources)
- Cooling sodium system (resource exhaust date is the year 2013)
- Control and emergency system, SUZ (beginning from 1994 its resource is determined in regular technical inspections for a time of 2 years. The present sanctioned period of operation is till 1.11.99 г.).

As it can be seen from Table 2 the first to exhaust is the mechanical resource of the movable reflector.

Table 3 illustrates variant 3 of the use of the IBR-2 remaining resource.

Beginning from 1999 the reactor operates in 8 cycles (2000 hours/year) at W=1.5 MW

In the year 2002 the PO-2R resource exhausts

By the year 2002 (inclusive) a new movable reflector, PO-3, is manufactured under auspices of the IBR-2 modernization project

In the year 2003 the existing movable reflector PO-2R is replaced by the new movable reflector PO-3 and the IBR-2 reactor continues to operate at W=1.5 MW for another 3 years till the resource expiration date of the fuel elements (TVELs) and the reactor jacket.

The reported new approach to the realization of the IBR-2 reactor modernization project is elaborated accounting for estimated financial situation in JINR at present and in the nearest years and makes it possible to

- Extend the first stage of the modernization project (designing and manufacturing of new equipment) till the year 2006.
- Reduce required annual financing to 500-600 k$/year.

In 1998 financing on the project was practically absent (see Table 4) and as a result, no scheduled modernization works were conducted.

NIKIET modified the structure of the methane-helium chamber of the cryogenic moderator (CM), which was necessary after 1997 unsuccessful plant tests. Some elements of the camera were manufactured anew.

In 1998, the main investigations of the IBR-2 reactor were conducted using standard techniques of monitoring reactor power noises and axial vibrations of the movable reflectors in each reactor cycle. There were investigated absolute deviations and spectral characteristics of noises. The main attention was given to comparative characteristics of the reactor noises state following the transition from 2 MW to a lower reactor power of 1.5 MW. Table 5 summarises some characteristics of reactor noises following the change in the average reactor power.

The Tables below show that after transition to a reduced power at a sodium consumption of 90 m^3/hour the reactor noises state has considerably improved. For example, uncontrollable power oscillations decreased, in average, by a factor of 1.75. The axial vibrations of the reflectors reduced by 16 to 29 %. Phase oscillations remained on nearly the same level. Such changes in reactor noises are in agreement with previous investigations whose results show that as the power decreases below 1.55 MW uncontrollable fluctuations of reactivity and correspondingly, energy oscillations in power pulses essentially decrease. Actually, at powers lower than 1.03 MW only mechanical vibrations of the movable reflectors and in part, sodium flow through the active zone, contribute to reactor noises. The latter component of noises affects the power at frequencies less than 0.3 Hz. At the power 1.5 MW fluctuations at frequencies higher than 1 Hz also depend on sodium consumption. Investigations show that during the 1997-1998 campaign absolute oscillations of noises slightly change in time while their spectral composition depends on the duration of reactor operation.

Table 1

Details of IBR-2 reactor operation in 1998 (as of 21.12.98)

№ cycle	Cycle start and end dates	Operation time for physical experiment Tph.e	Operation time of movable reflector Tmr	Number of emergency shutdowns N_{AS}	What caused emergency shutdowns (classified in accordance with РД-04-10-94)						Number of operating beams
					Voltage drops (PO8)	Equipment malfunctioning (PO7)	Electronic equipment malfunctioning (PO7)	Personnel errors (PO5)	Scheduled shutdowns	Malfunctioning of safety-important systems (PO4)	
1	19.01 - 30.01	260	274	1	0	0	1	0	0	0	11
2	09.02 - 20.02	266	275	0	0	0	0	0	0	0	11
3	10.03 - 21.03	262	271	1	0	0	1	0	0	0	11
4	6.04 - 17.04	Cancelled by the order of FLNP Directorate									
5	12.05 - 23.05	245	263	3	0	0	3	0	0	0	11
6	1.06 - 12.06	231	274	2	0	0	2	0	0	0	11
7	22.06 - 3.07	Cancelled by the order of FLNP Directorate									
8	19.10 – 30.10	261	273	1	0	0	0	0	0	1	11
9	16.11 – 27.11	250	263	2	0	0	1	1	0	0	11
10	07.12 – 18.12	268	275	0	0	0	0	0	0	0	11
	Total	**2043**	**2168**	**10**	**0**	**0**	**8**	**1**	**0**	**1**	

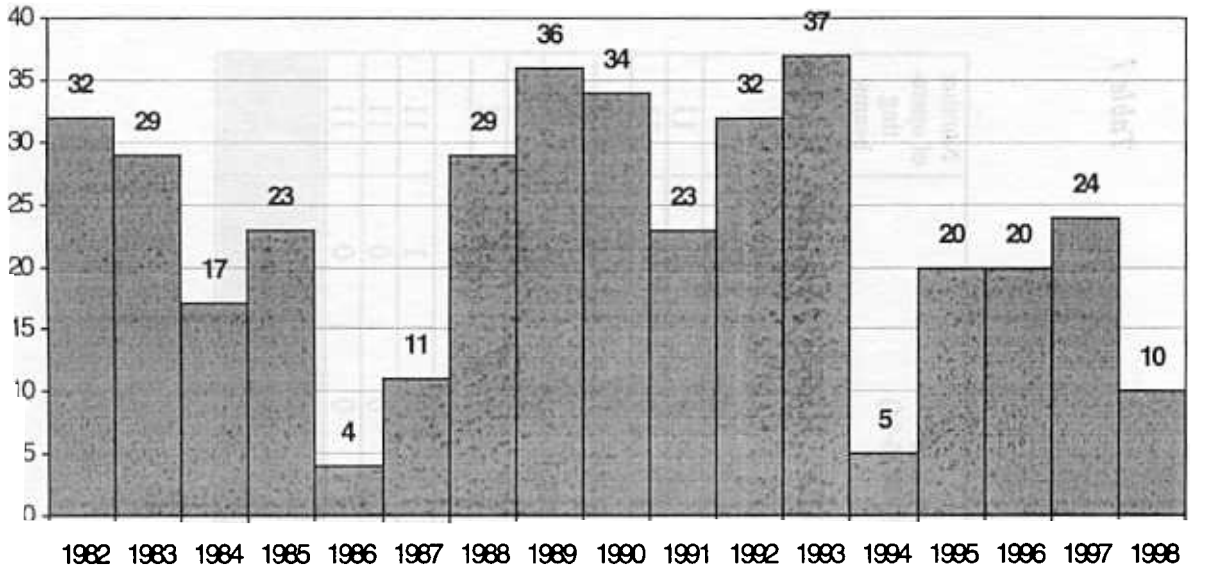

Fig.1. The number of emergency shutdowns per year.

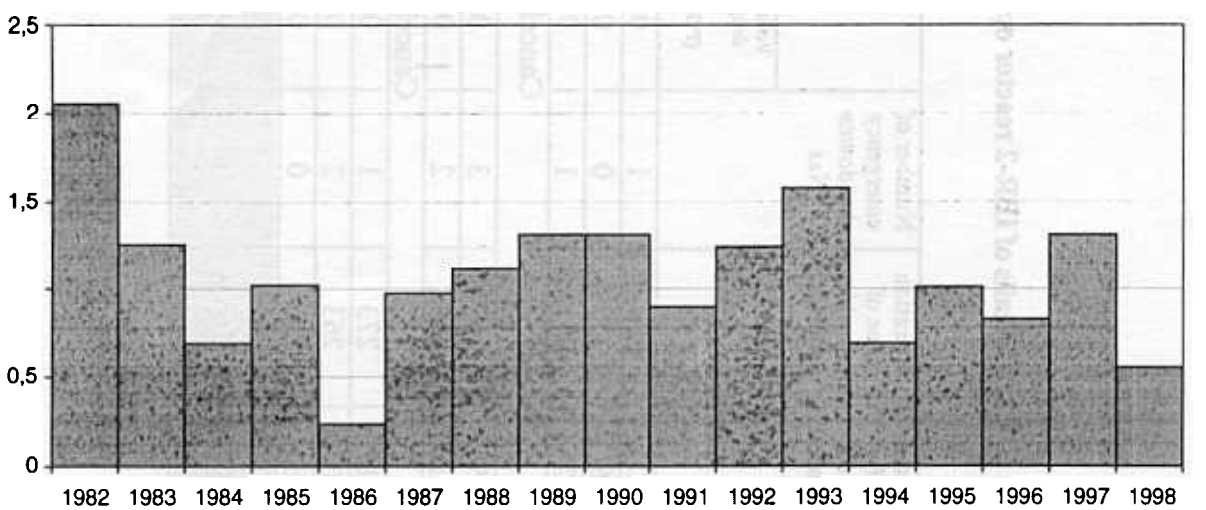

Fig.2. The number of emergency shutdowns per 100 hour-operation of the reactor.

Table 2

№		Limiting values	Used as of 1.10.98	Remaining resource in cycles	
				2 MW	1.5 MW
1.	**PO-2R** - mechanical - radiation	18000 hours 36000 MWhr	8700 hours. 13700 MWhr	34 44	34 60
2.	**Fuel elements (TVELs)** Burning	6.5% (E=8.5·10⁴MWhr	5.1% (E=6.4·10⁴ MWhr)	42	56
3.	**Jacket** - radiation - thermocyclic (n_{ES})	3.72·10²² n/cm? 550	2.82·10²² n/cm? 400	42 60	56 60

Table 3

Use of the IBR-2 remaining resource expressed in reactor cycles

№/Variant	Regime	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1	W = 2 MW τ_{phe} = 2500 hours	3	10	10	10	1 (8)*							
2	W = 1.5 MW τ_{phe} = 2000 hours	3	8	8	8	7 (22)							
3	W = 1.5 MW τ_{phe} = 2000 hours MR (PO-3 from the year 2003)	3	8	8	8	7	Replace-ment of MR (PO-2R)	8	7	7	2nd stage of project "IBR-2 Mdernization"		

*) *In brackets the remaining resource of the fuel elements TVELs) and the jacket is indicated for the case of MR PO-2R.*

Table 4

Payments to outside organizations in k$ for 1998 (as of 1.12.98)

	Budget		Nonbudget sources
	plan	Fact	
Exploitation	100	15.9	3.22
Modernization	1276	32.25	12.9
TOTAL:		48.15	16.12

Table 5

Mean square (σ) and maximal (Δ) vibrations of MMR (X), AMR (X), power oscillations (Q) and torsion vibrations of the reflectors (φ) for the reactor operation modes at 2 MW and 1.5 MW at a sodium consumption in the first contour of 90 m³/hour. The last column shows relative vibration/oscillation changes

Parameter	W = 2 MW	W = 1.5 MW	Relative changes
σQ/Q,%	9.5	5.4	1.76
ΔQ/Q,%	75	43	1.74
σX_{mmr}, mm	0.012	0.010	1.20
ΔX_{mmr}, mm	0.085	0.073	1.16
σX_{amr}, mm	0.053	0.041	1.29
ΔX_{amr}, mm	0.25	0.20	1.25
σφ, mcsec	24	23	~1
Δφ, mcsec	163	166	~1

2.2. THE IREN PROJECT

The project status. Following the recommendations of the JINR Plenipotentiary Committee (March 1993) the JINR Directorate adopted the decision, approved at the 76th Session of the JINR Scientific Council June 1994), to construct the new modern source of resonance neutrons for investigations in fundamental and applied nuclear physics. The completion date (physical startup date) was the end of 1997. The IBR-30 analogous scheme, i.e., the combination of a powerful linear electron accelerator and a subcritical multiplying target, was chosen for the new neutron source. The new IREN facility will permit the neutron energy resolution to be increased by an order of magnitude at a double increase in luminosity.

In 1998, financing of the work on the IREN project was lower than in 1997 and only extreme efforts of the project management made it possible for the project to survive. The problem of the IREN project implementation was re-examined in detail at the 84th session of the JINR Scientific Council. It was strongly recommended to accelerate the creation of IREN. As A result, the IREN completion date will be, at best, the end of the year 2001 on the condition of complete financing in the period 1999 - 2001. The IBR-30 shutdown and disassembly is respectively delayed till the middle of the year 2000.