2. NEUTRON SOURCES

2.1. THE IBR-2 PULSED REACTOR

In 1999, the reactor IBR-2 operated in accordance with the approved schedule. The details are given in Tables 1 and 2. The reactor operated for physical experiment a total of 8 cycles (1984 hr) at W=1.5 MW, including 3 cycles with a cryogenic moderator (CM).

As scheduled, the plan of reactor maintenance PMW-99 was executed from June to September. In the period, radioactive elements of MR-1 (movable reflector-1) were removed from a working storage by explosive techniques.

Work to improve control of a number of important systems of safety was conducted, including the formation of independent reference signals (5 Hz) in the channels of side pulses, introduction of a system of permanent control of the position of the emergency shutdown block (ESB) during power operation, upgrading of some measuring and control devices (MCD).

In October 1999, a license for the operation of the IBR-2 reactor was obtained from the State Atomic Inspection (SAI).

The main achievement of the year is the completion of work to build CM.

In the period from October 18 to December 17, 1999 the physical startup of the solid methane-based cryogenic moderator CM was carried out. The designing and manufacturing of CM were executed by the Scientific Research and Design Institute of Power Engineering in Moscow under the scientific guidence and with participation of FLNP JINR in Dubna.

The CM of IBR-2 is a third in the world solid methane moderator. The first two in Japan and USA, work in much less intense fields of radiation, however.

In accordance with the schedule of physical startup operations all three rated modes of CM were tested. Both technical and neutron-physical characteristics of the moderator proved to be as expected. In particular, it was shown that a small addition of ethylene reduces considerably the rate of the formation of radiolytic hydrogen which causes major difficulties in the use of solid methane as a moderator. For $\lambda \geq$ Å and the methane temperature 30 K, the neutron yield was 10-20 as much as from a usual water moderator (see Figs. 1, 2).

The flux from CM of IBR-2 exceeds that of the recently best source of cold neutrons at ISIS (England) having liquid methane as a moderating agent.

In 2000, CM IBR-2 will be operated in a regular mode.

In 1999, the concept of the reactor modernization underwent considerable changes. As a result, the improvement continues under the auspices of the program "Concept of the IBR-2 Modernization in the Period to the Year 2010".

In accordance with it work was carried out along the lines:

1) working drawings of MR-3;
2) preparations to start manufacturing of a new fuel loading. The technical and working design of TVEL is completed and manufacturing of the new elements of TVEL started;
3) work on the technical project of IBR-2 modernization started. Technical assignments for the modernization of control and emergency systems (CES) are prepared and technical requirements for the electronic equipment of CES are specified.

In 1999, the financing of the operation and modernization of IBR-2 improved considerably as compared to 1998 (see Table 3).

The main 2000 objectives.

Provide the physical program of beam measurements with a beam time in the volume of 2000 hr (8 cycles a year, including 3 cycles with CM).

2. Start manufacturing of MR-3.
3. Continue work to prepare a new fuel loading.
4. Technical project of the IBR-2 modernization, including CES of the reactor.

Table 1

IBR-2 operation parameters in 1999

Cycle	Dates	Time of operation for physical experiment Tph.ex.	Time of operation of movable reflector T_{MR}	Energy production E, MW*hr	Number of emergency shutdowns N_{ES}	Causes of emergency shutdowns (classified as in РД-04-10-94)				Number of beams in operation
						Voltage drops (PO8)	Equipment malfunctioning (PO7)	Electronic equipment malfunctioning (PO7)	Human factor (PO5)	
1	18.01 - 29.01	267	273	403	0	0	0	0	0	11
2	15.02 - 26.02	247	263	376	3	2	0	1	0	11
3	15.03 – 26.03	244	270	370	3	1	1	0	1	11
4	12.04 – 20.04	171	198	257	4	0	3	1	0	11
5	17.05 – 01.06	323	356	494	6	1	3	2	0	11
6	18.10 – 29.10	227	252	264	2	1	1	0	0	11
7	15.11 – 26.11	252	273	406	1	1	0	0	0	11
8	06.12 – 17.12	253	271	385	2	1	0	0	1	11
TOTAL:		**1984**	**2156**	**2955**	**21**	**7**	**8**	**4**	**2**	

Table 2

Current IBR-2 parameters

	Parameter	December 1999	Rated
1	Operation for physical experiment (th.hr)	36. 984	44
2	Generated energy (th.MWhr)	68.216	85
3	Operation of MR-2P(th.hr)	11.676	18*
4	Maximum fluence on the jacket in the center of the active zone (10^{22} n/cm^2):		
	$E_n > 0.5$ MeV	1.845	2.3
	$E_n > 0.1$ MeV	2.98	3.72
5	Maximum burn of fuel (%)		
	Brick-like TVEL	5.19	6.5
	rod-like TVEL	5.51	8.2
6	Number of emergency shutdowns	424	550

Note:

* *The resource is established in the process of reactor operation as a function of the MR state. The expected resource is indicated by analogy with MR-2.*

Table 3

IBR-2 expenditures in 1999 in k$ (paid to outside organizations)

	Budget	Non-budget
Operation and maintenance	67	18
Modernization	156	–
TOTAL:	**223**	**18**

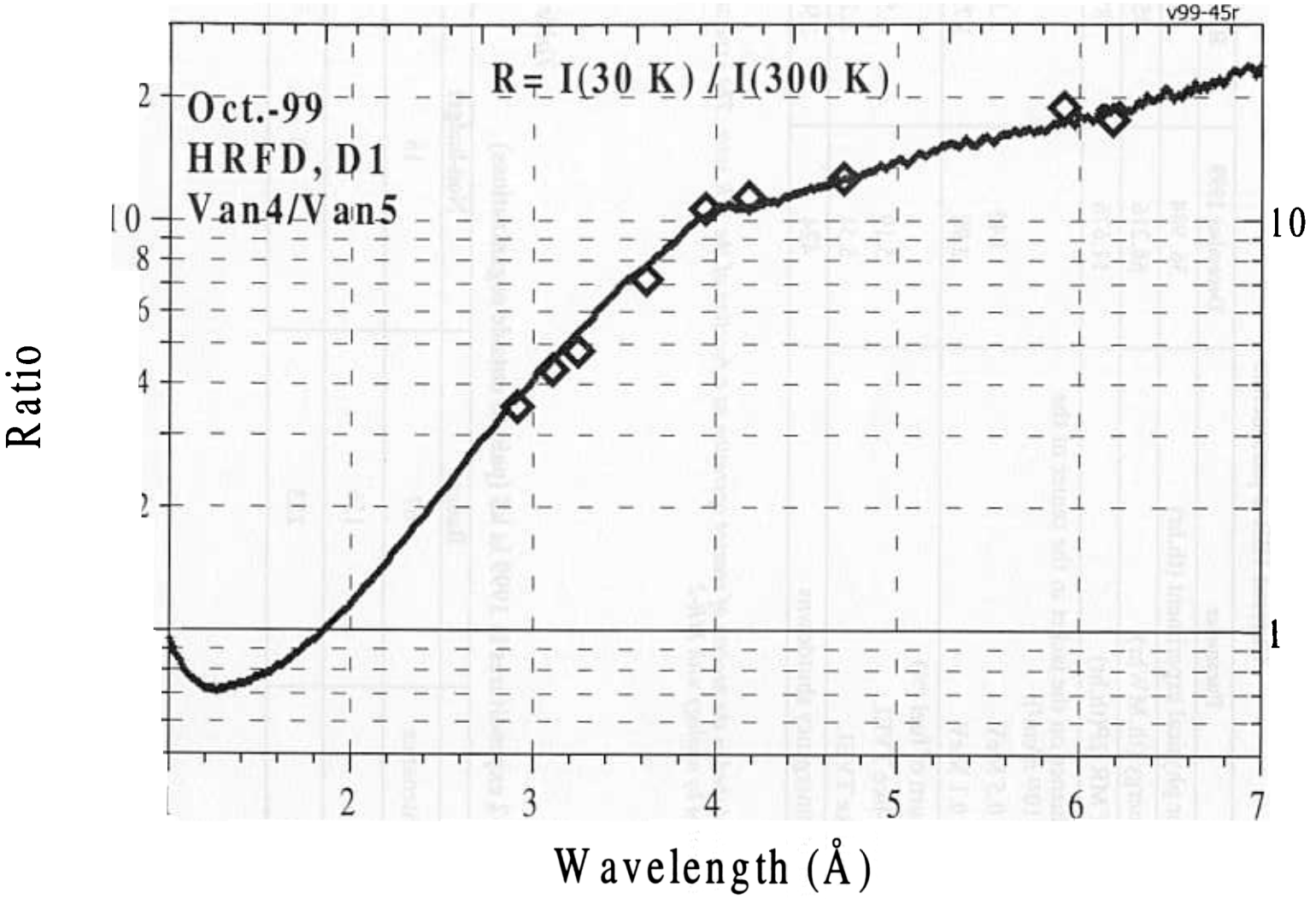

Fig.1. Relative changes of the initial spectra generated by the cryogenic and water moderators

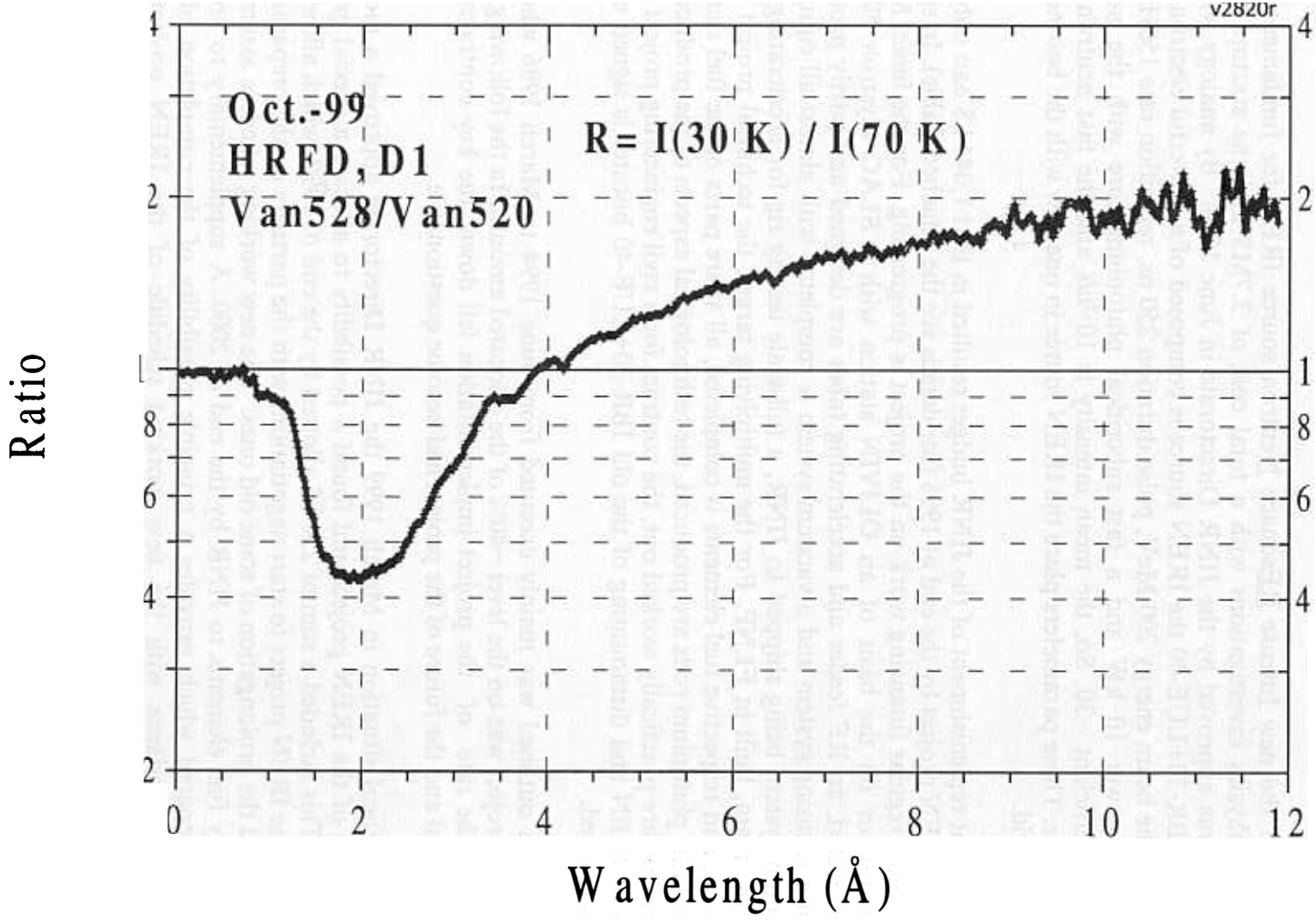

Fig.2. Relative changes of the initial neutron spectra generated by the cryogenic moderator at different temperatures

2.2. THE IREN PROJECT

The project of the new Intense REsonace Neutron source IREN for fundamental and applied nuclear physics investigations with a total cost of 3.7M$ and the startup date in December 1997 was approved by the JINR Directorate in June 1994. By analogy with the existing booster IBR-30+LUE-40 the IREN source is composed of a powerful electron linac, LUE-200, with the beam energy 200 MeV, pulse duration 250 ns, repetition rate 150Hz, and the mean beam power 10 kW and a fast subcritical plutonium core with the neutron multiplication coefficient ~30. So, the mean intensity is 10^{15}n/s and the fast neutron pulse duration is ~400ns. These parameters place the IREN source in one row with the best neutron sources in the world.

Insufficient replenishment of the JINR budget resulted in that 1,044 k$ had only been invested in the IREN project by the end of 1998 (for details see the attached Table). In spite of insufficient and irregular financing work on the project is progressing. For the linac: M-350, the first modulator on the basis of an OLIVIN station with a SLAC klystron 5045, is successfully tested, an RF feeder and accelerating tubes are designed and partly produced, designing of a focusing system and a vacuum system is completed with almost all equipment for the vacuum system being shipped to JINR, a full-scale testing rig for accelerating tubes trials is, in the main, built in FLNP. For the multiplying target: the technical project of the subcritical core and respective fuel elements is completed, all spare parts of the fuel elements, including metallic plutonium rods are produced, the technological aspects of the production of the fuel elements are practically worked out, the contract for a civil engineering project of the installation of IREN and dismounting of the old IBR-30+LUE-40 booster is signed and its first stage is realised.

The above outlined was mainly executed from June 1994 to March 1996 when the financing of the project was on the level ~40% of the allocated amount. In the following three years, however, the rate of the project implementation fell down, the key contracts were frozen or cancelled and the future of the project had become questionable.

In this critical situation in March 1999 the JINR Directorate approved a modified working schedule of the IREN project and found a possibility to allocate a special grant to save the project. This included a sum of 250 k$ allotted by the end of 1999, which allowed the management of the IREN project to start negotiations with the partners on the preparation of new contracts and the prolongation of some old ones. The new working schedule assumes the shipment of ready fuel elements to JINR by the end of 2000. A supplementary to previous agreements is prepared which provides a principle possibility of the completion of linac construction in accordance with the new working schedule of the IREN project. The implementation of financial plans in 1999 is illustrated in Table 4.

The modified working schedule of the IREN project, realized and planned investments in 1999-2002 are shown in Table 5. It is necessary to emphasise that the implementation of the new working schedule with a startup date at the end of 2002 requires the investment of not less than 560 k$, including the financing for the resuming of work in JINR laboratories, in 2000. However, increased financing in the coming years will not compensate for the delay in the project implementation as soon as each stage needs a definite time and should be included in the annual plans of partner-institutions.

Table 4

Financing of the IREN project in 1999

№	Activity	Contract №	Executing Institution	Initially scheduled payments in 1999	Modified payments schedule in 1999	Paid in the first half of 1999	To be paid by the end of 1999	Paid in the second half of 1999	Total payments in 1999
1	Design and manufacture of $W(^{10}B)_2$ reflectors for fuel elements	400/485	"Tyazhimpex"	1.5 k$	1.5 k$	1.5 k$	----	----	1.5 k$
2	Design and construction of fuel elements	400/482 400/483 400/612	Mayak plant VNIINM Tyazhimpex	300 KR 150 KR 3010 KR	300 KR 150 KR 3010 KR	---- ---- 1964 KR	300 KR 150 KR 1046 KR	250 KR 150 KR 1046 KR	250 KR 150 KR 3010 KR
3	Multiplying target Technical project Project of technical provision of safety Civil engineering project	 400/193 400/643 400/644 400/196 400/645	 NIKIET NIKIET RECON GSPI ECOPROECT	 12.7 k$ 45 k$ 27.9 k$ 66 k$ 65.6 k$	 12.7 k$ --- 5 k$ --- 5 k$	 12.7 k$ --- --- --- 	 --- --- 5 k$ --- 5 k$	 --- --- --- --- ---	 12.7 k$ --- --- --- ---
4	Design and construction of accelerating system of LUE-200	400/299	BINP, Novosibirsk	110 k$	80 k$	46 k$	34 k$	40 k$	86 k$
5	Construction of RF feeder	400/251	MEPI	15 k$	10 k$	---	10 k$	10 k$	10 k$
6	Equipment of full scale RF testing-rig	---	FLNP	15 k$	15 k$	----	15 k$	9.7 k$	9.7 k$
7	Stand of electron gun	---	FLNP, LHE, PPL	5 k$	5 k$	---	5 k$	---	---
8	Beam control system	---	FLNP, LHE	2.5 k$	2.5 k$	---	2.5 k$	---	---
	TOTAL			504.2k$	274.7 k$	139.2 k$	135.5 k$	117.9 k$	257.1 k$

Table 5

Time-table of the IREN project implementation in 2000-2003

Work	2000				2001				2002				2003			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Civil engineering project of IREN facility, including technical provision of safety																
Production of accelerating tubes, buncher and SLED system and shipment to JINR																
Construction of main linac systems and their test at full scale testing facilities of JINR																
Fuel elements manufacture, licensing and shipment to JINR																
Technological project of multiplying target construction																
Manufacture of the multiplying target and its auxiliary systems																
Licensing of shut down and dismounting of IBR-30																
Production of equipment for IBR-30 dismounting																
Dismounting of IBR-30 and LUE-40																
Reconstruction of Bld. 43 and IREN infrastructure																
Mounting of IREN linac and multiplying target in Bld. 43																
Startup, tests and adjusting of IREN																
Required funding (k$)	576				920				699				300			

Approved total cost of the IREN project - *3740 k$*
Invested in 1994-1999 - *1302 k$*
To be invested in 2000-2003 - *2438 k$*