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SCIENTIFIC PROGRAM OF THE FRANK LABORATORY OF NEUTRON PHYSICS: Report for 1997 and Prospects for 1998

Report of FLNP Director to the 83rd Session
of the Scientific Council of JINR
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БИБЛИОТЕКА

INTRODUCTION

In 1997, the FLNP scientific program was covered by six research themes of the JINR Plan of Scientific Research and International Scientific and Technical Cooperation (PSRISTC), and was aimed at obtaining new results in condensed matter physics (theme 07-4-0864-89/98 "Condensed Matter Investigations Using Neutron Scattering", headed by A.M.Balagurov), neutron nuclear physics (theme 06-4-0974-92/99 "Study of the Fundamental Characteristics of Neutrons and Nuclei", headed by W.I.Furman), and applied research (theme 07-4-0975-92/97 "Activation Analysis and Radiation Investigations at IBR-2", headed by V.A.Sarin). To effect scientific research, work to develop, modernize, and construct the FLNP basic facilities, IBR-2 (theme 07-4-0851-87/97 "Development and Upgrading the IBR-2 Complex", headed by V.D.Ananiev) and IREN (theme 06-4-0993-94/99 "IREN Project", headed by W.I.Furman), and the FLNP measurement and computation complex (theme 07-4-1012-96/2000 "Development of the FLNP Measurement and Computation Complex", headed by V.I.Prikhodko) continued. Also, FLNP took part in the JINR themes: "ATLAS. General-Purpose pp Experiment at the Large Hadron Collider at CERN" (theme 02-0-1007-94/97, headed by V.I.Lushchikov), "Theoretical and Experimental Investigations of the Electronuclear Method of Energy Production and Radioactive Waste Transmission" (theme 03-0-1008-95/99, headed by Yu.P.Popov).

This report contains a brief account of 1997 scientific results and the plans of the Laboratory for 1998 reflected in the JINR Plan of Scientific Research (PSRISTC) submitted for approval to the present session of the JINR Scientific Council. The FLNP annual report for 1997 will present a more detailed review of 1997 results.

1. THE RESULTS OF SCIENTIFIC INVESTIGATIONS IN 1997

1.1. Condensed Matter Physics

Experimental investigations. At the IBR-2 reactor, neutron diffraction investigations in condensed matter physics (theme 0864) are conducted using four main techniques: diffraction, small-angle scattering, inelastic scattering, and polarized neutron optics. The beam time is distributed in accordance with experts recommendations based submitted proposals and the existing long-term agreements for cooperation.

Twelve neutron beams are extracted to the IBR-2 experimental halls with physical setups. At present, experimenters have twelve spectrometers for investigations in condensed matter physics. In 1997, nine spectrometers operated in the user mode: HRFD, DN-2, NSVR, YuMO, SPN, REFLEX-P, KDSOG, NERA, and DIN. The DN-12 spectrometer was under radical modernization completed in the summer 1997. The SNIM spectrometer was removed from service in accordance with the recommendations of the Program Advisory Committee. The DIFRAN spectrometer operated according to the special program. The main parameters of the spectrometers included in the schedule and their sample environment systems have mainly been formed and are on the world level. During the regular summer maintenance shutdown of the reactor assembling of the SKAT spectrometer designed for texture investigations of bulk samples was completed. In place of the NSVR spectrometer, the SKAT spectrometer was put into operation at the end of 1997.

The number of countries from where applications for beam time were submitted has increased to 25.

Diffraction. The program for investigations of mercury-containing high-temperature superconductors carried out in cooperation with the Department of Chemistry of Moscow State University, was extended to a study of the atomic structure of $HgBa_2CuO_4F_\delta$, the compound where superstoichiometric oxygen is replaced by fluorine atoms. The idea of the experiment was to replace a bivalent by a monovalent doping element. In this case, the ionic nature of carrier formation in the superconducting plane together with retaining the charge balance would require a double amount of doping atoms at an equivalent superconducting transition temperature.

The initial Hg-1201 phase with T_c = 61 K was successfully fluorinated at Moscow State University using XeF_2. This first lead to an increase in T_c up to 97 K and then its decrease, with suppression of superconducting properties, as the fluorine content in the sample increased. The neutron diffraction analysis of two compositions of $HgBa_2CuO_4F_\delta$ conducted with the high resolution Fourier diffractometer at IBR-2 in May 1997 confirmed the fact of fluorine implantation into the charge reservoir (Hg-plane) and showed the double fluorine content in comparison with oxygen Hg-1201 phases with close T_c values. This fact is a strong argument in favor of the ionic model of electric charge carriers formation (holes) in Hg-1201 in doping.

In the framework of the study of the macroscopic phase separation phenomenon in crystals of superconductors, a series of experiments to investigate the transformation twinning of $La_2CuO_{4+\delta}$ crystals were conducted on the DN-2 diffractometer. The experiments on DN-2 were performed using a new two-dimensional position-sensitive detector which made it possible to scan the reciprocal space of the crystal in three or two coordinates without rotating the sample. The measurements showed that the domain (twin) structure of these crystals significantly differs from the classical scheme realized when the axis of the fourth order disappears, and observed, for instance, in KDP and Y-123 crystals. It turned out that the boundaries between the domains in La_2CuO are mainly coherent (the portion of the domains conjugated by an incoherent boundary is small). What is more, in crystals that experience macroscopic phase separation this portion is no more than several per cent, and this apparently favors the diffusion of superstoichiometric oxygen that leads to the separation.

Small angle scattering. The micelle-vesicle transition in a phospholipid /sodium cholate/ water system was investigated with the YuMO small-angle scattering spectrometer. The morphological and structural changes in the system under changes of temperature and detergent concentration were studied. For a dimyristyl-phosphatidyl-choline-based system, a transition from the multilamellar to the unilamellar structure whose formation goes through the stage of the generation of lengthy rod-like micelles, was observed. In addition, the analysis of the YuMO data allowed us to determine the geometric characteristics of nascent micelles.

Polarized neutron optics investigations. On SPN, the first experiments to generate and register neutron standing waves were performed. The development of this method can help to solve the problem of the determination of structural positions of atoms near or on the surface of matter. In the experiment, the intensities of γ-quanta emitted following neutron capture in a thin gadolinium layer (~ 50 E) coated on a magnetized Fe layer (~ 1000 E thick) were measured as a function of the incident neutron beam polarization. The preliminary analysis of the measured dependence makes it possible to suggest that the neutron standing wave was observed with the probability of about 90%.

On the new polarized neutron reflectometer REFLEX concurrently with its comprehensive attestation, experiments to study the properties of some neutron-optic systems: multilayer mirrors, an interference filter for the UCN, etc. were conducted. Owing to a high

resolution of the reflectometer, which appears to be a record one nowadays, we can obtain information on fine details of surface layers.

Inelastic neutron scattering. On the NERA spectrometer, investigations of the dynamics of ammonium and methyl groups in the phase transitions in stoichiometric compounds (of the $(NH_4)_2SO_4$ type) and in solid solutions (of the $(NH_4)_{2-x}Rb_xSO_4$ type) were carried out. The replacement of ammonium ions by Rb which has almost the same ionic radius, introduces some kind of disorder into the system of hydrogen bonds. This allows us to follow the influence of disordering on the dynamics of ammonium. The system of $(NH_4)_{2-x}Rb_xSO_4$ has been studied over a whole range of concentrations ($0 \le x \le 2$) and a wide range of temperatures ($10 \le T \le 300$ K) by neutron diffraction, inelastic, and quasielastic scattering. This made it possible to complete the determination of the phase diagram of the compound, in which the triple point of a transition to the ferroelectric phase was found. The obtained inelastic scattering spectra were used to verify the microscopic model of the dynamics of these crystals. This model allowed us to explain satisfactorily the mechanism of the observed phase transitions and the role of the dynamics of ammonium in the formation of the ferroelectric properties of crystals.

In 1997, on the KDSOG spectrometer the number of external users and as a result, the number of investigated problems have increased sharply. These include measurements of crystalline fields in HTSC and GMR materials, determination of phonon spectra in ferroelectrics, intermetallic compounds based on Ni_3Al, amorphous alloys with isotopic substitution in a Zr-Ni system, and nitrous steels, studies of hydrogen vibrations in nonequilibrium ω-Ti and Zr, an intermetallic compound FeTi, and complex carbo- and nitro-hydrides. One of the interesting results is the detection of a change in the magnetic response when doping the $AlSr_2Er_{1-x}Ca_xCu_2O_7$ (1212) compound. This allowed us to construct a model of "charge redistribution" in the CuO_2 planes. The experiments to verify the model over a wide range of doping have been proposed.

On the DIN spectrometer, traditional experiments investigating the atomic dynamics of liquid-metal systems with gas impurities, relaxation characteristics of liquid helium, dynamics of hydrogen in triple interstitial systems on the basis of transition metals of the Vth group, were continued to verify and systematize earlier data.

1.2. Neutron Nuclear Physics

According to the recommendations of the VII-th session of the JINR Program Advisory Committee for nuclear physics in the frame of scientific theme -0974- the limited research program was realized in 1997 on the basis of the IBR-30 and other neutron sources. The following main results were obtained.

Methodological investigations. The fist test measurements with the UGRA instruments have shown that it is necessary to modernize previously constructed neutron detectors to adjust these to operation in vacuum conditions. The work was carried out at the end of 1997 but in the absence of the IBR-30 neutron beams it turned out impossible to test new detectors.

The new set-up KOLHIDA transferred from Georgia in 1996 was mounted on beam 11 of the IBR-2. This installation allows the use of intense beams of polarized neutrons to study nuclear pseudomagnetism and some new parity violation effects in neutron optics.

The new ionization chamber for measuring (n,p)- and (n,α)-reactions with gaseous nuclear targets was constructed and tested. The first measurements of some targets with rather small cross-sections demonstrated good agreement with previously published values for ^{17}O and

^{36}Ar nuclei and very strong disagreement for ^{21}Ne that has the smallest cross-section. The created technique may be very useful for measurements of radioactive gas samples of ^{37}Ar and ^{39}Ar important for clarifying the nature of the nucleosynthesis of the rare isotope ^{36}S.

Significant advances have been made in the creation, together with Lebedev Institute, of a neutron polarizer based on optical pumping of a ^{3}He gas sample. Test measurements are planned for 1998.

Experimental investigations. The program of experiments to study nuclear fission by resonance neutrons continued successfully. An analysis of the experimental data on the P-even right-left asymmetry of fission fragments α^{rl} and the P-odd angular correlation α^{nf} between the neutron spin and the fragment momentum measured with polarized neutrons, was completed. The α^{rl} and α^{nf} values of 10^{-3} were measured as a function of the neutron energy up to 30 eV with a high accuracy. This makes it possible to conduct their quantitative analysis.

Since these correlations as well as the previously measured forward-backward correlations are caused by the interference of s- and p-wave amplitudes in the (n,f)-reaction and, in addition, there is no information on the fission amplitudes of p-wave neutron induced fission, it is necessary to have information on respective s-wave amplitudes to realize the quantitative analysis of the whole data set. To obtain unambiguous information, the experimental statistics of measuring the angular anisotropy of fission fragments from the neutron induced fission of an aligned ^{235}U target was increased two times in 1997 over the neutron energy interval $0 \le E_n \le 30$ eV. A multi-level four channel analysis of the data obtained during 1996-1997 was performed for an extended interval of neutron energy by two codes - the original code developed in FLNP and the modified SAMMY code. The original code was modified to include options for the analysis of s-p-wave interference effects. A combined analysis of the whole data set is now in progress.

Neutron resonances were first measured in the ^{243}Am(n,f)reactions with a fast ionization chamber that makes it possible to register fission fragments against high α-particle background ($N_f/N_\alpha \sim 10^{-10}$). This opens good possibilities of measuring earlier unknown fission cross-sections of other actinides over the resonance region.

Very high statistics ($50 \cdot 10^6$ events) was achieved in measurements of mass & TKE distributions of fission fragments from the ^{235}U(n,f)-reaction for $E_n \le 15$ eV. The mass resolution was nearly unity.

In the frame of a TRIPLE collaboration P-odd neutron transmission was measured for ^{106,108}Pd target nuclei to study the nuclear mass dependence of the pseudoscalar components of the weak nucleon-nucleus interaction.

The temperature behavior of the cross section of partial losses of ultracold neutrons, namely, upscattering was investigated in ILL from room temperature to 80 K. The obtained results show that inelastic upscattering is the main loss causing process even at 80 K. This allows the assumption that the anomaly in UCN storage on the beryllium surface at 10-15K[1] can be explained by UCN upscattering. It is necessary to conduct further experiments for the 10-80K temperature interval to verify or violate this assumption. The proposal for such experiment was accepted for 1998.

On the basis of a modified gravitation UCN spectrometer with interference filters in ILL an experiment to verify precisely the dispersion law of neutron waves in matter was carried out. The obtained results indicate the existence of anomalous UCN dispersion. The investigations will continue in 1998.

1.3. Applied Research

Applied investigations at the IBR-2 reactor were carried out in the following directions.

Neutron activation analysis. In 1997, on the IBR-2 irradiation channels investigations of distributions of rare-earth metals and other elements in environmental objects and in new materials were carried out.

A series of multielement NAA studies of ecological samples from the Kola peninsula to investigate technogenic transformation of podzolic Al-Fe-soils as a result of air pollution by copper-nickel production and the first stage of the International Program for the study of atmospheric depositions of heavy metals on the territory of Romania were completed.

The analytical studies of the NAA&RR sector in analyzing rocks, soil, sediments and water have made a significant contribution to the development of the experimental interrepublican system of ecological monitoring of the basin of the Terek river.

In 1997, investigations of semiconducting crystals of the A^3B^6-$A^3B^3C^6_2$ type with a highly anisotropic crystalline lattice structure continued. The electric and photoelectric properties of the heterojunction (HJ) in a TlSe - $TlInSe_2$ system obtained by the liquid-phase epitaxy method from a TlSe melt on the surface (110) of $TlInSe_2$ are described in the framework of the model of an isotypical HJ without local states in the interface.

Neutron diffraction. Applied investigations were carried out with the HRFD diffractometer (internal stresses in bulk samples, determination of the structure of activated catalyzers) and the NSVR spectrometer (texture of geological materials). In particular, on HRFD Al_2O_3/Al composite compounds with a ceramic matrix were studied. The development of the technology of producing advanced materials resulted in a new technique for manufacturing composite compounds, when metal is infiltrated into a porous ceramic matrix under gas pressure, and forms a deeply penetrating reticular microstructure. In the process, fragile ceramic materials are strengthened by inserting an elastic phase, usually metal. This makes it possible to improve the mechanical characteristics of the composite compounds. On HRFD, two series of Al_2O_3/Al composite compounds with an average size of metal insertions of 0.1 μm and 1 μm were investigated.

1.4. Other JINR Programs

Project ATLAS. A complex of investigations (together with CERN, Max Planck Institute in Munich and a number of other institutes) of the radiation resistivity of electronic circuits and different construction materials used for building physical instruments for the LHC accelerator under construction were carried out to select materials resistant to radiation damage at a total γ-dose of up to 15 Mrad and a fast neutron fluence up to 10^{16}-10^{17} n/cm^2.

Theoretical and Experimental Investigations of the Electronuclear Method of Energy Production and Radioactive Waste Transmission. In 1997, work to investigate fast neutron yield fluctuation in the subcritical system reactor + electron beam of LUE-40 and study the dependence of the neutron yield on reactor subcritical level was carried out.

2. NEUTRON SOURCES

2.1. The IBR-2 Pulsed Reactor

In the first half of 1997, The IBR-2 reactor operated for physical experiments for 1060 hours in 4 cycles. On June 12, 1997, the reactor was shut down because of malfunctioning of the prompt emergency shutdown system (the system could not be set in the operative position).

It took much time to execute the technical decision made together with the Chief Designer (NIKIET). According to the corrected plan, the startup took place in November, 1997

Modernization project. Work to modernize the circulating water system has been performed allowing a more economical regime of water supply when the reactor does not operate. Experimental investigations into the dynamic properties of the IBR-2 reactor have been carried out. The main result of these studies is that after the second reloading (1996) the reactor operates stably with the sodium flow rate 80-120 m^3/h over the whole power range (up to 2 MW). The reserve power supply of IBR-2 from the Ivankovskaya hydroelectric power station in emergency cases from the GPP-2 reserve control desk has been improved.

Cryogenic moderator. Work to manufacture the CM cryogenic moderator is completed in the main. However, plant tests have revealed the necessity of modifying the CM structure to ensure the CM reliability. This will delay the ultimate date of manufacture till the middle of 1998.

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 an order of magnitude at a double increase in luminosity.

In 1997 financing of the work on the IREN project became lower than in 1996 (30 K$ per year) and only extraordinary efforts of the project management allowed to preserve validity of the key contracts ensuring construction of the main IREN systems. So to the initial completing date of the IREN project established at the official beginning of the project in 1994 we have at least two years delay. To the end of 1997 in the frame of the project implementation it was invested 870 K$ and the total cost of the signed contract achieved 2700 K$. In spite of lack of financing minor progress took place in design and construction of the electron gun (at LHE and LPP), the RF system of the LUE-200 and the full scale stand for testing the accelerating systems of the linac (at FLNP). The first variant of the control system for the IREN was created and will be tested during 1998 at the IBR-30.

The situation with implementation of the IREN project was considered by the special expert committee formed by the JINR Directorate and by the 7th session of the Program Advisory Committee for nuclear physics. Both committees strongly recommended the JINR Directorate to seek possibilities for completing the project in 1999-2000.

Appendix 1 shows the information on financing research and design work at the IBR-2 reactor and the IREN project in 1997. Appendix 2 presents the schedule of IREN and IBR-2 financing in 1997.

3. THE FLNP MEASUREMENT AND COMPUTATION COMPLEX

The network and computer infrastructure. In 1997, new communication equipment of the CISCO firm was installed and put into operation in the FLNP local computing network (LCN). This made it possible to switch over to data-transfer rates of up to 100 Mbits/s in the FLNP network. The installation of the new network equipment and software has made it possible to sharply reduce the number of collisions in the network and the load onto the Backbone when exchanging large data arrays.

Development of electronic equipment. In the reported year we gained experience in using VME data acquisition systems at the NERA-PR, NSVR, and SKAT spectrometers. During the autumn cycles of IBR-2 the software of the VME-system at HRFD was debugged. Work to manufacture and adjust unified electronics for position-sensitive detectors at the DN-2 and YuMO spectrometers is being completed. Similar electronics are being created for SPN and DN-12. Trouble-free operation of the experiment automation systems at IBR-2 and IBR-30 has been afforded.

4. SCIENTIFIC RESEARCH PLAN FOR 1998

The 1998 FLNP Scientific Research Plan contains 5 first priority themes.

Theme	Leader	Priority	Code
Neutron scattering investigations of condensed matter	A.M.Balagurov	1	07-4-0864-89/98
Study of the fundamental properties of neutrons and nuclei	W.I.Furman	1	06-4-0974-92/99
Development and modernization of the IBR-2 complex	V.D.Ananiev, V.L.Aksenov	1	07-4-0851-87/2002
Realization of the IREN project	W.I.Furman	1	06-4-0993-94/99
Development of the information and computation infrastructure of FLNP and creation of the new generation of experiment automation systems	V.I.Prikhodko	1	07-4-1012-96/2000

In 1998, in the framework of theme 0864 investigations will be carried out in condensed matter physics in the following directions:

- *startup of position-sensitive detectors for DN-2 and YuMO;*
- *further development of experiments to determine the structure of ribosome subparticles at YuMO*
- *further investigations into the structure of new compounds at HRFD;*
- *completion of the SKAT spectrometer;*

- *completion of the modernization of DN-12;*
- *manufacturing position-sensitive detectors for the SPN and REFLEX-P spectrometers;*
- *completion of the first modernization stage of SPN;*
- *studies of standing neutron waves on SPN by detecting α-particles instead of γ-rays.*

The majority of experiments with the IBR-2 spectrometers will be performed in the frame of the user policy. Because of a malfunction in the reactor operation in 1997 (the cycles in February, June, and October were canceled and the cycle in May was shortened), some experiments scheduled for the reported year will be shifted to 1998.

The following main tasks are to be solved in 1998 in the framework of theme 1012:

- *improve qualitatively the parameters of the LCN disk space (to increase the capacity and the reliability) by purchasing a disk subsystem of the RAID type and connecting it to the SUN-cluster;*
- *to install a fast network commutator in the segment of the IBR-2 experimental setups and connect the equipment via twisted pairs;*
- *replace some of the SUN2 workstations by ULTRA1;*
- *to put into operation VME data acquisition systems at some of the IBR-2 spectrometers;*
- *to design and construct new electronic blocks;*
- *to develop and support the software of the spectrometers and LCN*
- *routine maintenance of the measuring systems of the spectrometers at IBR-2 and IBR-30.*

Applied research using instrumental neutron activation analysis, radiation action, and other nuclear physics methods will be continued.

The following main tasks are to be solved in 1998 in the framework of theme 0851:

- *Providing 2500 hours of beam time for physical experiments necessary to execute the accepted program of physical research.*
- *Physical start-up of CM.*
- *Resuming work to manufacture new TVELs.*
- *Resuming design and construction work to modernize IBR-2.*

In 1998, the main task of the direction "Neutron nuclear physics" will be the realization of the IREN project:

- *approval and financial support of the work schedule of the IREN project adjusted to the completion date at the end of the year 2000;*
- *completion of the manufacturing and licensing of TVELs;*
- *development of working drawings and technical substantiation for the safety and reliability of the multiplying target;*
- *continuation of the manufacturing of the main systems of the LUE-200 accelerator and the completion of the creation of a full-scale stand;*
- *design and modeling of the auxiliary systems of the IREN facility.*

The IBR-30+LUE-40 will be used as a working stand to adjust, model and test the IREN systems. Due to the fact that the implementation of the IREN project proceeds with at least two years delay the installation IBR-30+LUE-40 has to be in operation up to the middle of 1999. During this time it will be used not only as a working stand but also as a neutron source for the realization of the research nuclear physics program in accordance with the recommendations of the VIIth session of the JINR Program Advisory Committee for nuclear physics.

The following research program will be realized at the IBR-30 as well as other neutron sources (theme 0974):

to perform first precise measurements of neutron scattering using the UGRA installation;

to continue the complex program for investigating the nuclear fission of ^{235}U induced by resonance neutrons;

to continue the program for investigating the phase transition in excited nuclei by the $(n, 2\gamma)$ reaction method;

to obtain new data for astrophysics with radioactive noble gas samples;

to realize first test measurements with the installation aimed to study time invariance violation in the interaction of neutrons with nuclei;

to continue the research program with UCNs at the BIGR (Sarov) and ILL (Grenoble) reactors to study the neutron lifetime, the anomaly in the heating of UCN, and the dispersion law of neutron waves in matter.

5. CONFERENCES AND MEETINGS

In 1997, FLNP organized the following meetings:

1. International Seminar "Structure and Properties of Crystalline Materials" SPCM, March 4-7.

2. V International Seminar on Interaction of Neutrons with Nuclei ISINN-5, May 13-16.

3. National Conference on X-ray, Synchrotron, Electron and Neutron Investigations RSNE-97, May 26-29.

4. International Workshop on Data Acquisition Systems for Neutron Experimental Facilities DANEF'97, June 2-4.

5. International Seminar "Neutron Analysis of Textures and Stresses",NTSA, June 23-27.

In 1998, FLNP will organize the following meetings:

1. *International Seminar "Collective Effects in Condensed Matter", March 7-15, Pamporovo, Bulgaria.*
2. *VI International Seminar on Interaction of Neutrons with Nuclei ISINN-6, May 13-16.*
3. *International Workshop on Deuteration of Biological Molecules for Stuctural and Dynamic Studies, May 19-25.*
4. *II International Seminar "Ferroelectrics-relaxors", June 23-26.*
5. *VIII International School on Neutron Physics, August 30 - September 5.*

Appendix 1

INFORMATION
on financing research-and-design work at the IBR-2 reactor and the IREN project in 1997
(as on 01.12.97)

I. IBR-2

1. Planned financing from the FLNP budget for 1997 (research-and-design work) — 900 thous. $
2. Planned financing from the JINR directorate grant (research-and-design work) — 150 thous. $
3. Execution as on 01.12.97 — 139,11 thous. $

For routine maintenance of IBR-2

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Payment in thous. $	0,0	0,0	8,8	13,15	22,4	0,0	2,6	28,2	1,0	2,7	0,0		78,85

For modernization of IBR-2

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Payment in thous. $	0,0	0,0	0,0	6,96	0,0	0,0	0,0	30,1	2,6	20,6	0,0		60,26

Total for IBR-2

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Payment in thous. $	0,0	0,0	8,8	20,11	22,4	0,0	2,6	58,3	3,6	23,3	0,0		139,11

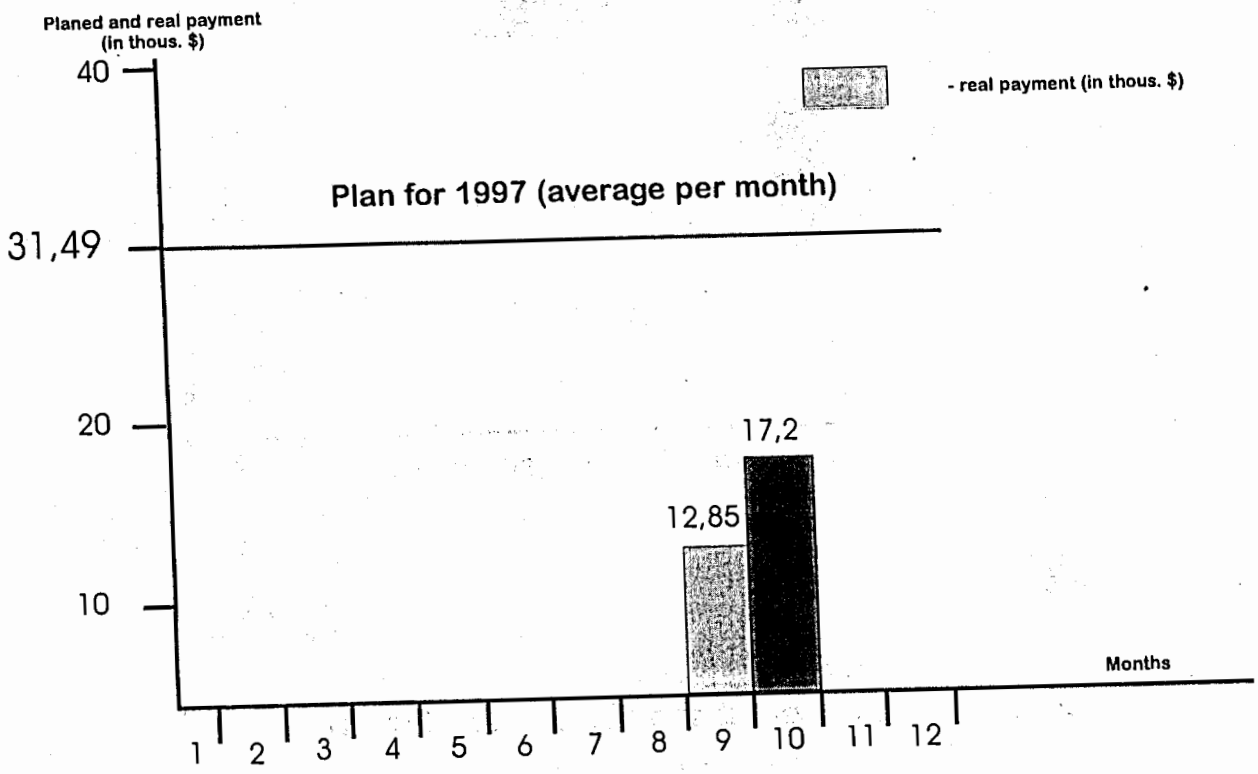
II. IREN

1. Planned financing from the FLNP budget for 1997 (research-and-design work) — 77,9 thous. $
2. Planned financing from the JINR directorate grant (research-and-design work) — 300 thous. $
3. Execution as on 01.12.97 — 30,05 thous. $

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Payment in thous. $	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,85	17,2	0,0		30,05

Appendix 2

Schedule
of financing research-and-design work at the IREN project in 1997
(as on 01.12.97)



Schedule
of financing research-and-design work at the IBR-2 reactor in 1997
(as on 01.12.97)