607188, the Nizhny Novgorod Region,
Sarov, pr. Mira, 37
Tel: (83130) 4-48-02
Fax: (83130) 2-94-94
http://www.vniief.ru
E-mail: staff@vniief.ru

By the Decree of the Council of Ministers of the USSR All Russian Research Institute of Experimental Physics (hereinafter referred to as VNIIEF) (which is FSUE "Russian Federal Nuclear Centre" now) was established in 1946 to design and develop nuclear weapons.

VNIIEF is unique enterprise which preserved and developed computing, research, design and production facilities in one process cycle. VNIIEF specialists were repeatedly commissioned to solve top priority nation-wide level tasks.

Institute's activities led to termination of the US monopoly in nuclear field and to nuclear parity during the Cold War.

Institute's office building

The main task of the Institute is to provide and maintain reliability and security of nuclear weapons in Russia.

VNIIEF comprises a few institutes, namely: Institute of Theoretical and Mathematical Physics (ITMP), Institute of Experimental Gas Dynamics and Explosion Physics (IEP), Institute of Nuclear and Radiation Physics (INRP), Institute of Laser and Physical Research (ILPR) as well as Scientific and Research Centre for High Energy Density Physics (SRCP), a number of design bureaus and special-purpose centers.

INRP has R&D Divisions, engineering and manufacturing complexes, departments, services and workshops dealing with neutronic and simulation studies, have critical test benches (facilities) and research pulse reactors, electron accelerators, irradiation complexes, physical facilities with plasma focus, magnetic cumulative generators, powerful light source and explosion-type shock test bench. The employees study radiochemistry and analytic chemistry, develop radioelectronics, automatize control and monitoring systems for complex physical facilities, systems of security, control and

V.E. KOSTYUKOV,
VNIIEF Director

accounting of nuclear and radioactive materials non-proliferation, take part in the international projects (CERN – the Big Bang Theory, basic research in high energy physics).

Nuclear research facilities are gathered at INRP's Division of Applied nuclear physics and nuclear-physical facilities.

N.V. ZAVJALOV
INRP Director

Personalities

VALERY BASMANOV
Chief Engineer of INRP, PhD (Eng.Sc.), Lenin Komsomol prize winner

SERGEY VORONTSOV
First Deputy Director of INRP, PhD (Phys&Math)
From 1999 till 2010 was a head of "Reactor Division"

ANDREY DEVYATKIN
Head of "Reactor Division", PhD (Phys&Math)

ALEXEY NAROZHNY
Deputy Head of "Reactor Division" for researches at RR and CF

YURY DEMIN
Deputy Head of "Reactor Division" for engineering and technical aspects

IGOR SMIRNOV
Leading Researcher, PhD (Phys&Math)
Was a head of "Reactor Division" from 1989 till 1999, was First Deputy Director of INRP for nuclear facilities and fissionable materials from 1999 till 2010

VLADIMIR KOLESOV
Leading Researcher, Dr. Sc. (Phys&Math), professor
Was a head of Design and Theoretical Department from 1965 till 2010. Was directly involved in the development of RR and CF in service. Wrote "Aperiodic pulse reactors" monograph

MIKHAIL KUVSHINOV
Leading Researcher, Dr. Sc. (Phys&Math)
Was directly involved in the development of RR and CF in service

IGOR NIKITIN
Head of design group, PhD (Eng.Sc.)
Was directly involved in the development of RR and CF in service

VNIIEF's nuclear research facilities in service

NRF type	NRF name	Thermal power, kW	Year of first criticality
RR	BIGR	500.00*	1977
RR	BR-1M	5.00*	2009
RR	BR-K1	10.00*	1995
RR	VIR-2M	25.00*	1980
RR	GIR-2	1.00*	1993
CF	IKAR-S	–	2008
CF	FKBN-2M	–	2001

* *In static mode*

BIGR GRAPHITE-MODERATED FAST PULSE REACTOR

BIGR RR is a fast pulse reactor with ceramic (UO_2+C) core. The reactor is categorized as aperiodic self-quenching pulse reactor and designed for physical tests.

Works on reaching first criticality in the reactor were conducted from February till December, 1976. Reactor was commissioned on 31.03.1977. Designed life was not specified. Estimated core material life is not less than 3000 pulse startups with maximum power density.

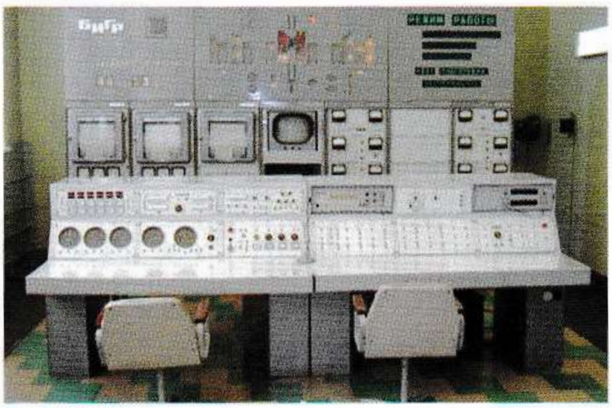
The reactor was not reconstructed. Automatic physical characteristic measurement system was modernized. CPS is being modernized.

BIGR can be operated in three modes:

- static mode – operation at steady-state power;
- quasi-pulse mode – pulses are generated on delayed neutrons;
- pulse mode – pulses are generated on prompt neutrons.

BIGR reactor is fixed in the centre of the hall with dimensions of 11.5×10×8 m. Core centre is located at 1.7 m above the floor.

Reactor core is made in shape of hollow cylinder (with the diameter of 76 cm and height of 67 cm) and consists of free-hanging coaxial unfixed rings. Each ring rests upon the neighboring one or upon the external case by circumferential ledge made at ring half-height. The core is divided in 3 units, namely: fixed unit, coarse reactivity adjustment unit and fine reactivity adjustment unit. Steel tube is used as pulse unit. The core is enclosed in a leaktight vessel filled with helium.



BIGR control room

View of BIGR core

BIGR main performance

Static mode

Power density per pulse .... Up to 500 MJ

Maximum power .... 0.5 MW

Quasi-pulse mode

Maximum power density .... 280 MJ

Minimum quasi-pulse half-width .... 0.5 s

Power in a quasi-pulse peak .... Up to 1.5 GW

Pulse mode

Maximum power density .... 280 MJ

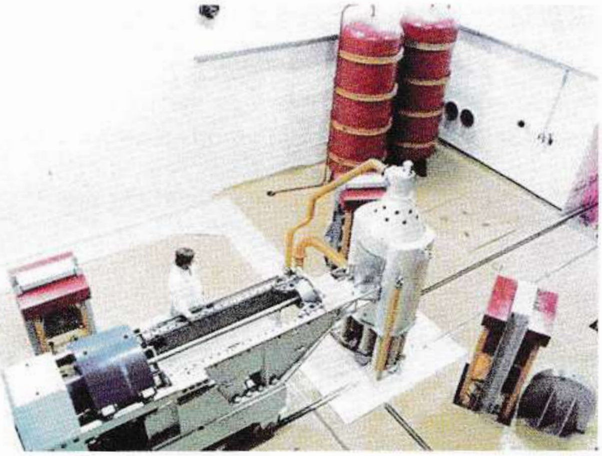
Minimum pulse half-width .... 2 s

Power in a pulse peak .... Up to 75 GW

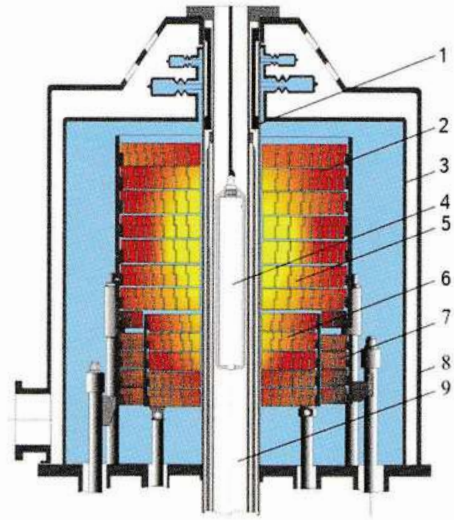
Pulse generation frequency is one pulse a day.

Mixture of compacted and sintered UO_2 (enrichment in ^{235}U is 90%) and graphite is used as core fuel.

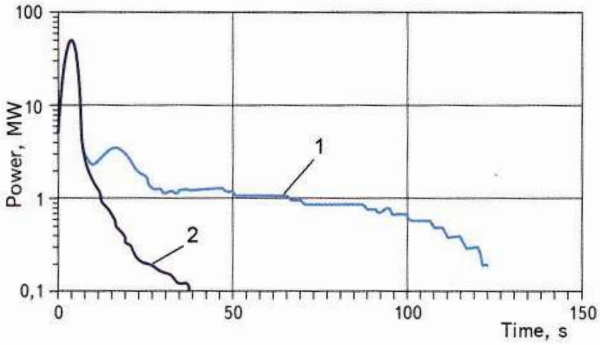
Reactor core is cooled after the pulse and during operation at steady-state power by either natural convection or forced one due to air vent through air-cooled shroud and central channel.



BIGR central hall



BIGR reactor section:
1 – pulse unit; 2 – fixed part of the core; 3 – core vessel; 4 – irradiation sample cask; 5 – core fuel rings; 6 – coarse reactivity adjustment unit; 7 – fine reactivity adjustment unit; 8 – air-cooled shroud; 9 – centerline chamber



Shape of fission pulse on prompt neutrons in BIGR reactor:
1 – pulse when pulse rod stops in the centre of the core; 2 – pulse when pulse rod flies through the core centre

BIGR experimental capabilities

– Samples can be housed within the 55 cm-high central channel loading cask, Ø10 cm, during radiation resistance tests.

– Large-sized samples can be remotely delivered to the core on specially designed trolleys from two opposite sides.

– The facility is equipped with additional equipment which makes it possible to vary n-γ-radiations in a greater range, namely: different n-γ-converter modifications, large-sized reflectors made of steel, graphite, polyethylene and beryllium.

The following modes of fission pulse generation are being used at the reactor:

– generation of fission pulses on prompt neutrons in flyby mode – pulse rod flies through the core centre;

– generation of fission pulses on prompt neutrons when pulse rod stops in the centre of the core;

– generation of fission pulses on prompt neutrons in case of initiation from power or powerful source of delayed neutrons;

– quasi-pulse mode – pulses are generated on delayed neutrons.

Pulses on delayed neutrons (quasi-pulses) can be of various shapes including rectangular one. Fission quasi-pulses have triangular shape at initial reactor runaway period within the range from dozens of seconds to hundreds of milliseconds. Fission quasi-pulses at the same periods but with power control have trapezoidal shape. Quasi-pulses have a shape close to rectangular when reactor reactivity is near to critical.

Main areas of studies

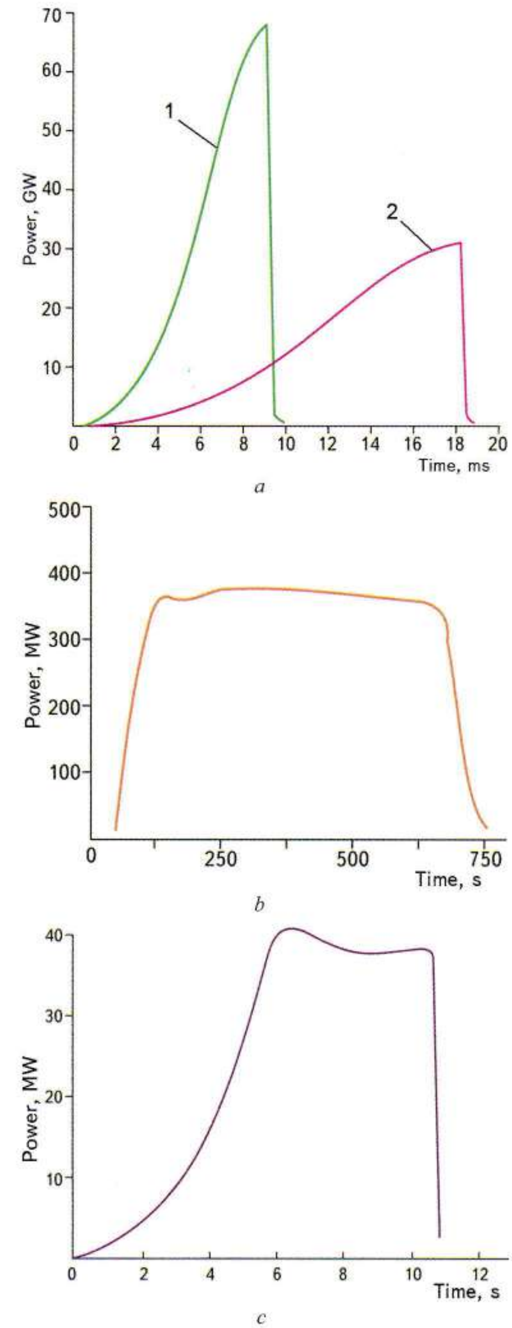
– Radiation-resistance tests

– Study of nuclear pumped lasers

– Study of BIGR fuel life (carbon pickup)

– Study of fuel sample behavior in reactivity-initiated accident (RIA)

Experiments on generating ultracold neutrons and studying their properties were conducted at BIGR reactor in cooperation with JINR specialists (Dubna).



BIGR quasi-pulse shape:
a – with runaway period 1.3 s (1) and 3.1 s (2); b – with runaway period 14.7 ms; c – with runaway period 1.3 s and with power control

Coated particle fuel before and after its irradiation in BIGR reactor

BIGR irradiation characteristics at power density of 280 MJ

Total neutron fluence in the central channel of the core .... $1 \cdot 10^{16}$ cm^{-2}

Neutron fluence (E > 0.1 MeV) in the central channel of the core .... $8.5 \cdot 10^{15}$ cm^{-2}

Maximum accompanying γ-radiation dose rate in the central channel of the core .... $1.9 \cdot 10^{4}$ Gy

Total neutron fluence on the core surface ...... $1 \cdot 10^{15}$ cm^{-2}

Neutron fluence (E >0.1 MeV) on the core surface .... $0.8 \cdot 10^{15}$ cm^{-2}

Maximum accompanying γ-radiation dose rate on the core surface .... $2.2 \cdot 10^{3}$ Gy

LM-8 eight-channel laser module used in tests of nuclear pumped lasers at BIGR reactor

VVER fuel samples after their irradiation in BIGR reactor

International cooperation

Under ISTC project No3119, coated particle fuel resistance was studied in reactivity-initiated accident with the support of General Atomics specialists (the USA).

Negotiations with KAERI specialists (South Korea) on award of the contract for studying fuel sample behavior in RIA are underway.

Main activities

Lifetime reactor operational characteristics are 594 startups in the static mode and 1046 pulses on prompt and delayed neutrons.

Modernization of automatic physical characteristic measurement system has been completed. The system makes it possible to record pulse shape, form quasi-pulse shape, record scram system signals, measure its response time and measure reactor core temperature.

Long-term agreement on experimental study of VVER fuel at BIGR reactor to develop fuel safety criteria in design-basis RIA has been concluded.

CPS is planned to be modernized.

Personalities

VLADIMIR BOGDANOV
Head of the laboratory where BIGR reactor and FKBN-2 CF are operated. Headed BIGR operation group for a long time

Contact person

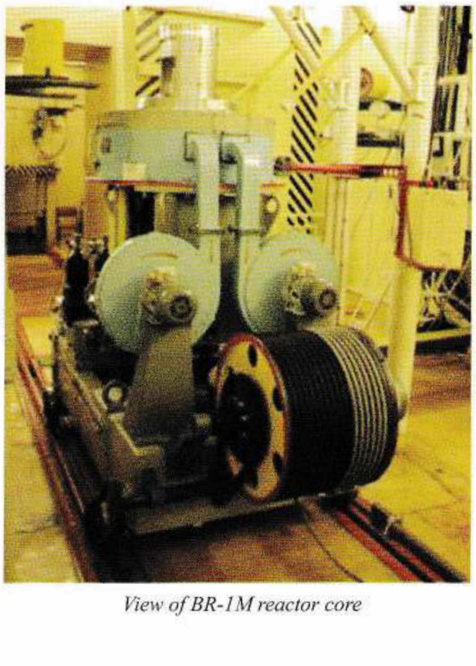
ANDREY PICHUGIN
Head of BIGR operation group
Tel (83130) 4-07-62
Fax (83130) 2-87-06
otd04@expd.vniief.ru

MODERNIZED BOOSTER-REACTOR BR-1M

BR-1M (modernized) research reactor is a fast pulse reactor with metal (U+Mo) core. The reactor is categorized as aperiodic self-quenching pulse reactor and designed for physical tests.

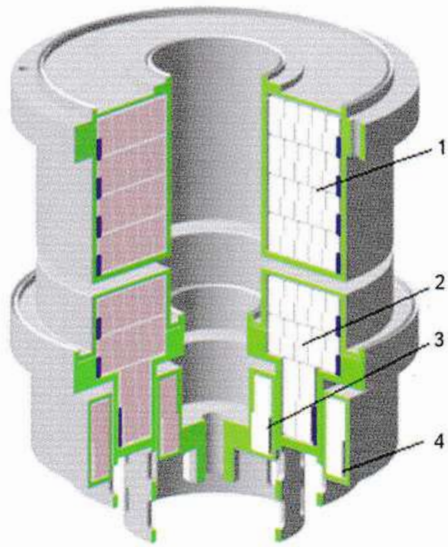
Before modernization, BR-1 reactor which was commissioned for the first time in 1979, operated till 1986. In 1990 BR-1 reactor with a new set of fuel elements was commissioned independently in a new building. In 1993, the mode when LIU-30 powerful electron linear induction accelerator and BR-1 reactor operated simultaneously was implemented. BR-1 reactor was modernized, which led to significant changes in the core design. The main differences of new core design are as follows:

– all fuel elements were manufactured from alloy of HEU (90 % enrichment in ^{235}U) with Mo (10 mass %) (alloy with 9 mass % Mo was used previously);



View of BR-1M reactor core

BR-1M control room



BR-1M section:
1 – fixed unit; 2 – movable unit; 3 – pulse unit; 4 – control unit

BR-1M main performance

Static mode

Power density per pulse .... Not limited

Maximum power.. 5 kW

Quasi-pulse mode

Maximum power density .... 10.6 MJ

Minimum quasi-pulse half-width .... 50 s

Power in a quasi-pulse peak .... Up to 200 kW

Pulse mode

Maximum power density .... 8 MJ

Minimum pulse half-width .... 70 s

Power in a pulse peak .... Up to 100 GW

Pulse generation frequency is one pulse a day.

– core structural division was enhanced;

– gaps between fuel elements were changed;

– rounded radii in ledge and side areas of all fuel elements were enhanced;

– welded joint was used as sealing element of the core structural units.

The same made it possible to reduce thermal and mechanical stresses in fuel elements, significantly increase core element lives and enhance safety during reactor operation. Life is specified for core fuel elements only and does not exceed 3000 pulses on prompt neutrons.

Works on reaching first criticality in the reactor were conducted from 26.11.2007 till 15.04.2009. Reactor was commissioned on August 10, 2009.

BR-1M can be operated in three modes:

– static mode – operation at steady-state power;

– quasi-pulse mode – pulses are generated on delayed neutrons;

– pulse mode – pulses are generated on prompt neutrons.

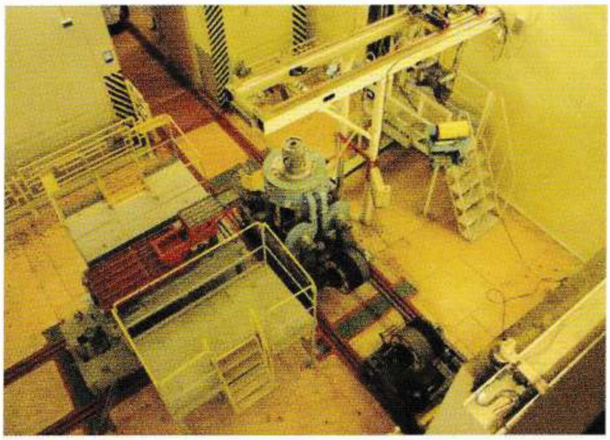
Reactor core has a shape of hollow cylinder (dimensions in closed state are 76 cm in diameter and 67 cm in height) and consists of 4 units, namely: upper, lower, control and pulse units. Fuel elements (rings) involved in units are housed in stainless steel shrouds filled with helium.

To reduce thermal shock-induced mechanical stresses the core (upper and lower units) is divided in 7 rows of free-hanging coaxial unfixed rings (4 rows with 5 fuel elements in each in the upper unit; 2 rows with 5 fuel elements in each in the upper unit and one row with 2 fuel elements in each in the lower unit). Ring thickness along the radius is 1.5 cm. Each ring rests upon the neighboring one or upon the external case by circumferential ledge made at ring half-height.

Reactor core is cooled after the pulse by either natural convection or forced one produced by two fans. Cooling air goes from the reactor hall to the fan, to the core and then to the reactor hall again.

BR-1M experimental capabilities

Samples can be housed within the 28 cm-high central channel loading cask, Ø9.4 cm, during radiation resistance tests.



BR-1M central hall

BR-1M irradiation characteristics at power density of 8 MJ

Total neutron fluence in the central channel of the core	$7.6 \cdot 10^{14}$ cm^{-2}
Neutron fluence (E > 0.1 MeV) in the central channel of the core	$7.4 \cdot 10^{14}$ cm^{-2}
Maximum accompanying γ-radiation dose rate in the central channel of the core	$2.1 \cdot 10^{3}$ Gy
Total neutron fluence on the core surface	$2.2 \cdot 10^{14}$ cm^{-2}
Neutron fluence (E > 0.1 MeV) on the core surface	$2.1 \cdot 10^{14}$ cm^{-2}
Maximum accompanying γ-radiation dose rate on the core surface	459 Gy

Large-sized samples can be positioned outside the core in any place of the reactor hall with dimensions of 22×12×8 m.

MOP-K simulating reference neutron field complex was designed and qualified using BR-1M reactor. This complex includes areas, Ø50 mm, in the central channel of the core and at the distance of 200, 715, 1013, 1565, 2215, 3300, 5500 mm from the core centre. MOP-K complex is admitted for use as reference facility as per GOST 8.105-80. It can reproduce differential neutron spectra within the range from 10^{-10} to 18 MeV and neutron fluence from 10^{7} to 10^{15} cm^{-2}.

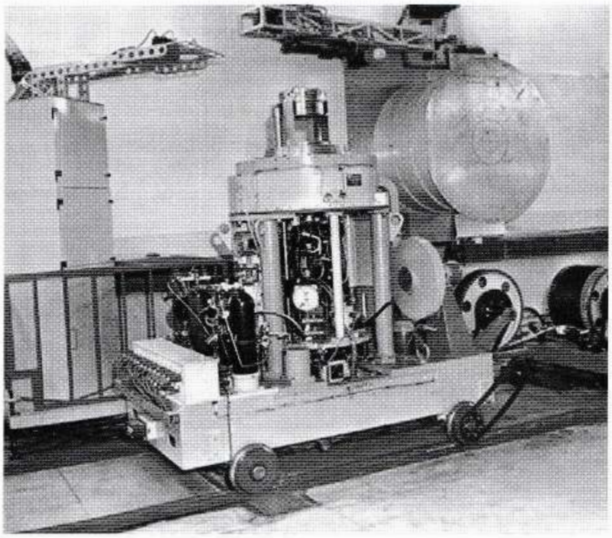
Also the reactor has EI-T-22 thermal neutron source. Its design is a graphite wedge, 1600×1200×1100 mm, which is piled up from units inside a rigid steel frame. Thermal neutron field is generated in the inner channel, 1200×200×200 mm. A device for positioning samples in specified points of thermal neutron field generated by EI-T-22 source is provided at the inner channel inlet. Thermal neutron fluence produced at power density of 1MJ is $2.7 \cdot 10^{11}$ cm^{-2}. If core fission rate is maximum, thermal neutron flux is ~$4 \cdot 10^{9}$ cm^{-2}·s^{-1}.

Main areas of studies

- Radiation resistance tests
- Safety study of research reactors with metal core.

International cooperation

Under ISTC project No2033, the studies were conducted with the support of SNL specialists



BR-1M reactor by LIU-30 accelerator outlet window

(the USA). These studies made it possible to develop procedure for testing integrity of fuel elements in terms of power fluctuation shape in the pulse "tail".

Main activities

Lifeime reactor operational characteristics are 49 pulses on prompt neutrons and 61 pulses on delayed neutrons. BR-1 with two cores of previous design generated 883 pulses on prompt neutrons.

The mode when LIU-30 powerful electron linear induction accelerator and BR-1 reactor operated simultaneously was fulfilled at Pulsar irradiation complex. This mode provided maximum possible bremsstrahlung dose rate and neutron fluence at minimum possible distance between outlet window of a focusing device and the reactor core centre.

CPS, pulse measurement system and reactor pneumatic system are planned to be modernized.

Contact person

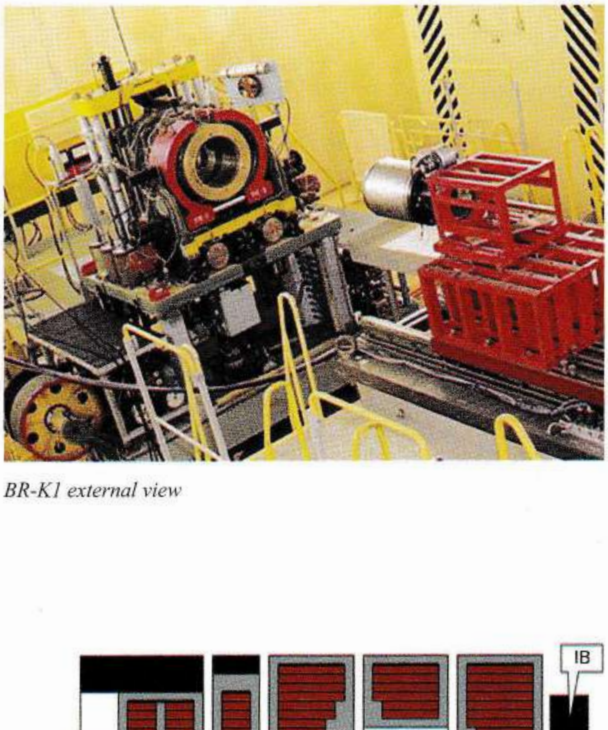
MAXIM MOCHKAEV
Head of BR-1M operation group
Tel. (83130)4-07-62
Fax (83130)2-87-06
otd04@expd.vniief.ru

BOOSTER-REACTOR BR-K1

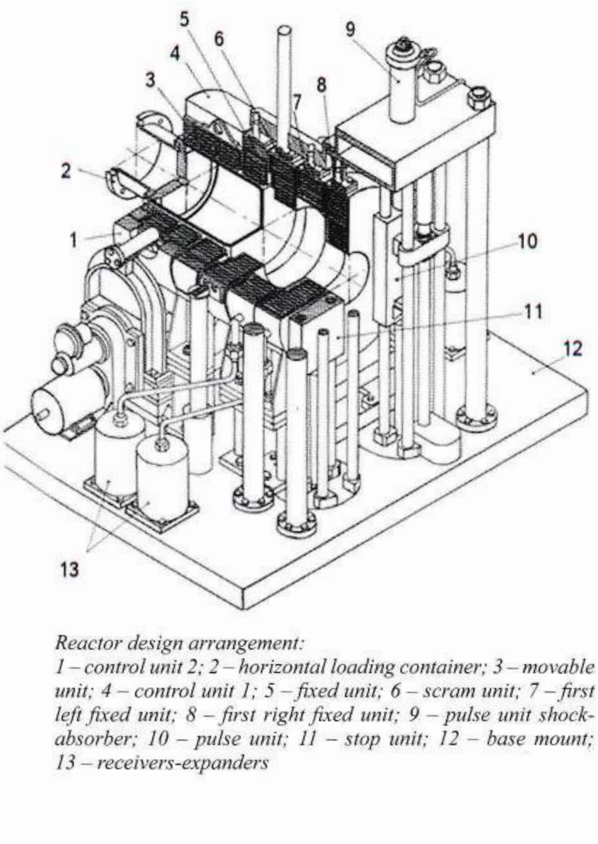
BR-K1 research reactor is a fast pulse reactor with metal (U+Mo) core. The reactor is categorized as aperiodic self-quenching pulse reactor and designed for physical tests.

Works on reaching first criticality in the reactor were conducted from 1986 till 1994. Reactor was commissioned on 30.11.1995.

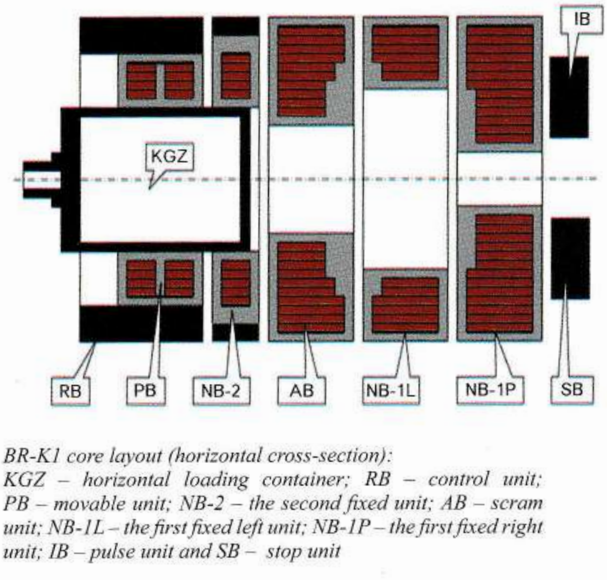
In 1997 BR-1K trial operation was suspended and then was resumed in December, 2005. To meet safety requirements the mode of pulse generation on prompt neutrons was eliminated



BR-K1 external view



Reactor design arrangement:
1 – control unit 2; 2 – horizontal loading container; 3 – movable unit; 4 – control unit 1; 5 – fixed unit; 6 – scram unit; 7 – first left fixed unit; 8 – first right fixed unit; 9 – pulse unit shock-absorber; 10 – pulse unit; 11 – stop unit; 12 – base mount; 13 – receivers-expanders



BR-K1 core layout (horizontal cross-section):
KGZ – horizontal loading container; RB – control unit; PB – movable unit; NB-2 – the second fixed unit; AB – scram unit; NB-1L – the first fixed left unit; NB-1P – the first fixed right unit; IB – pulse unit and SB – stop unit

BR-K1 main performance

Static mode

Power density per pulse .... Not limited

Maximum power .... 10 kW

Quasi-pulse mode

Maximum power density .... 30 MJ

Minimum quasi-pulse half-width .... 5 s

Power in a quasi-pulse peak .... Up to 5 MW

Pulse generation frequency is one pulse a day.

BR-K1 control room

(by both technical and organizational means) at BR-K1 reactor. BR-K1 reactor is being operated in static (operation at steady-state power) and quasi-pulse (generation of pulses on delayed neutrons) modes. The reactor was not reconstructed. Design life was not specified.

Reactor core is made in shape of hollow cylinder and has ring design, i.e. it is divided in disks (units), and disks, in their turn, are divided in coaxial rings. Core units are enclosed in leaktight stainless steel shrouds filled with helium. Horizontal orientation of the core is BR-K1 salient feature.

The core is made of alloy of enriched uranium (36 % in ^{235}U) and molybdenum (9 mass % Mo).

Beryllium pulse and stop units are used to generate pulses.

Reactor core is cooled by natural convection.

BR-K1 experimental capabilities

BR-K1 reactor is used in radiation resistance tests of hardware, instrumentation, devices, components, electronic devices, quantum electronic devices and others.

Samples can be housed within the 36 cm-long horizontal loading container, Ø30 cm.

Large-sized samples can be positioned outside the core in any point of the reactor hall with dimensions of 14×10×8 m.

MOP-K2 simulating reference neutron field complex was designed and qualified using BR-K1 reactor. This complex includes the following neutron fields located in the horizontal loading container chamber:

- in the point at a distance of 60 mm from the bottom of empty horizontal loading container (along the horizontal centerline) housed in the central experimental channel of the core;
- in the same point, but horizontal loading container houses lead sleeve ("lead filter") with 50 mm-thick walls;
- in the same point, but horizontal loading container houses n-γ-converter (NGK) which was manufactured from compact mixture of polypropylene and 10 mass % of cadmium oxide.

MOP-K2 complex is admitted for use as reference facility as per GOST 8.105-80. It can reproduce differential neutron spectra within the range from 10^{-10} to 18 MeV and neutron fluence from 10^{7} to 10^{15} cm^{-2}.

Also dedicated gamma source (DGS) was designed and qualified using BR-K1 reactor. DGS was spatially combined with MOP-K2. DGS was qualified as per absorbed dose and absorbed dose rate and designed for calibrating special-purpose devices.

BR-K1 irradiation characteristics at power density of 30MJ

Neutron fluence:

in the chamber .... $5.1\cdot10^{14}$ cm^{-2}

on the core surface .... $5.1\cdot10^{14}$ cm^{-2}

Accompanying γ-radiation dose rate:

in the chamber .... $2\cdot10^{3}$ Gy

on the core surface .... $0.15\cdot10^{3}$ Gy

Main areas of studies

– Radiation resistance tests

– Calibration of various gamma dose and dose rate detectors using qualified DGS. Priority is placed on calibration of vacuum-gamma emission detectors.

Main activities

Lifetime reactor operational characteristics are 115 startups in the static mode and 49 pulses on delayed neutrons after operation has been resumed. Before the reactor was shut down in 1997, about 30 pulses on prompt neutrons had been generated in the reactor.

Scheduled requalification of simulating reference neutron field complex was carried out.

Reactor is planned to be modernized. Design of external shrouds of the core structural units will be improved to achieve power density in the pulse on prompt neutrons close to the design one (~75 MJ).

Contact person

Alexander Koshelev, leading researcher, PhD (Phys&Math), the RF Government Prize winner, head of BR-K1 operation group. Headed development of BR-1(M) and BR-K1 reactors and headed the laboratory, which operates the mentioned reactors, for a long period.

ALEXANDER KOSHELEV
Head of BR-K1 operation group
Tel (83130) 4-07-62
Fax (83130) 2-87-06
otd04@expd.vniief.ru

WATER-COOLED PULSE REACTOR VIR-2M

VIR-2M research reactor is a pulse reactor with solution-type core. The reactor is categorized as aperiodic self-quenching pulse reactor and designed for physical studies.

VIR-2M reactor is the latest version of VIR-type facilities, the first of which was commissioned in 1965. Reactors were modernized due to improvements in the core vessel design.

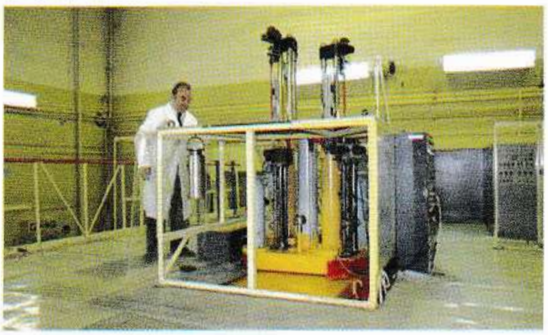
Works on reaching first criticality in the reactor were conducted in 1979-1980. Reactor was commissioned on 28.04.1980.

In 1996 reactor operation was suspended to conduct scheduled replacement of the vessel because of its design life exhausted. VIR-2M reactor with a new vessel was commissioned on 24.04.2001.

Design life of VIR-2M with a new vessel is not more than 3000 pulses on prompt neutrons. In addition, after generation of 1500 pulses but not later than 10 years from the date of reactor commissioning the reactor should be inspected by the dedicated commission to assess the possibility of its further operation.

VIR-2M can be operated in two modes:

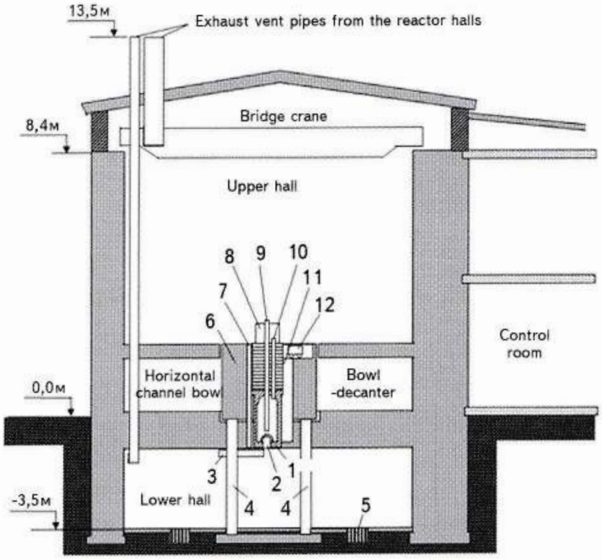
- static mode – operation at steady-state power;
- pulse mode – pulses are generated on prompt neutrons.



VIR-2M upper hall (biological shielding lid)

VIR-2M lower hall (LUNA two-channel laser facility is under hemispherical experimental channel)

VIR-2M control room



Schematic vertical section of VIR-2M premises: 1 – core vessel; 2 – hemispherical channel; 3 – lower shielding valve gate; 4 – support columns; 5 – emergency solution receiver; 6 –biological shielding unit; 7 – transit channel; 8 – control rod drives; 9 – central channel; 10 – fuel channel; 11 – vault; 12 – upper shielding valve gate

The core vessel is housed in the floor structure between two reactor halls located one above the other. Lower side of the vessel (with hemispherical channel) is on the lower hall ceiling level. The reactor is surrounded with biological shielding (minimum concrete thickness is 1.5 m) from all sides except for the lower one. Biological shielding has 3 more channels close to the core surface, namely: side channel, flyby channel and "vault".

VIR-2M core uses water-based uranyl sulphate (enrichment is 90% in ^{235}U) solution as fuel. Fuel solution volume is 104.6 l (U concentration – 67.9 g/l, U mass – 7.1 kg).

VIR-2M main performance

Moderator................Water contained in the fuel solution

Reflector..Core vessel walls (stainless steel) and biological shielding unit (concrete)

Static mode

Maximum power...25 kW

Power density per pulse..........................Not limited

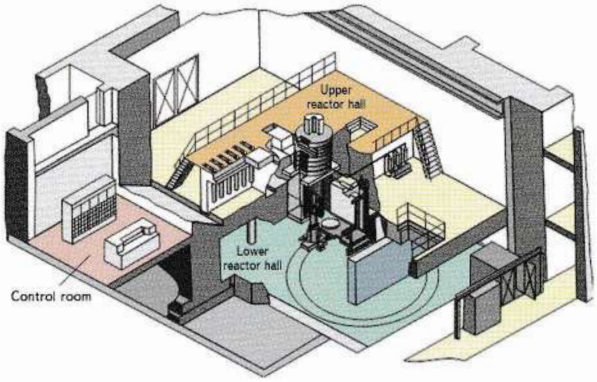
Pulse mode

Maximum power density................................56 MJ

Minimum pulse half-width.............................2.7 ms

Power in a pulse peak..........................Up to 20 GW

Pulse generation frequency is one pulse a day.



VIR-2M-based facility layout

Fuel solution is filled into leaktight strong cylindrical vessel made of stainless steel. Vessel bottom has hemispherical channel. Central channel and 6 control rod channels located uniformly in circle, are welded to the vessel lid.

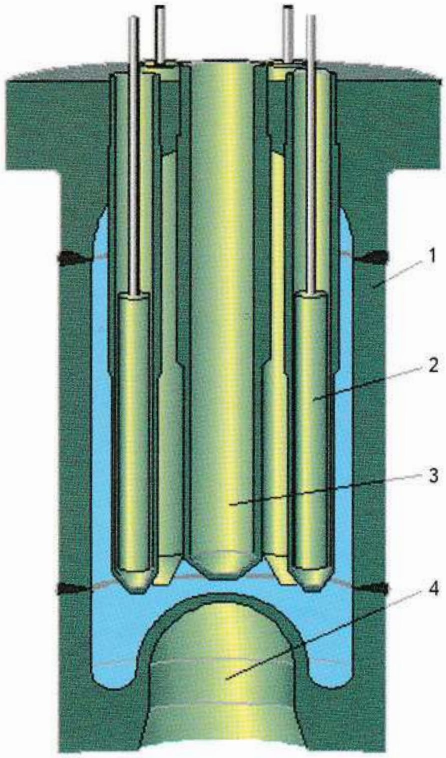
VIR-2M reactor is controlled using 6 lithium hydride rods. RS-1 and RS-2 control rods with scram system electromagnets are moved only by electromechanical drives, and a pair of pulse rods – only by pneumatic drive. Another pair of rods is equipped with the drive, which makes it possible to use them as both control rods and pulse ones.

Reactor core is cooled after the pulse and during power operation by either natural convection or forced one. To do this the reactor has a water jacket located outside the lower part of

VIR-2M irradiation characteristics at power density of 56 MJ

Total neutron fluence in SEC pole	$6.5 \cdot 10^{14}$ cm^{-2}
Total neutron fluence at CEC bottom	$6.3 \cdot 10^{14}$ cm^{-2}
Neutron fluence (E > 0.1 MeV) in SEC pole terminal and at CEC bottom	$3.9 \cdot 10^{14}$ cm^{-2}
Maximum accompanying γ-radiation dose rate in SEC pole and at CEC bottom	$4 \cdot 10^{3}$ Gy
Total neutron fluence on the core vessel surface	$1.0 \cdot 10^{14}$ cm^{-2}
Neutron fluence (E > 0.1 MeV) on the core vessel surface	$0.6 \cdot 10^{14}$ cm^{-2}
Maximum accompanying γ-radiation dose rate on the core vessel surface	430 Gy

the core and water cooling pipeline with three tubular heat exchangers cooled with water of the secondary circuit, which is connected to water supply system. Water jacket can also be used to heat the core (reactivity change method). In this case, heating line with four electrical heaters is connected to the water jacket.



VIR-2M core cross-section:
1 – core vessel; 2 – reactivity control rod; 3 – central experimental channel; 4 – hemispherical experimental channel

VIR-2M experimental capabilities

VIR-2M reactor is used in radiation resistance tests of hardware, instrumentation, devices, equipment, electronic devices, quantum electronic devices and others. Also reactor is the basic facility for studying nuclear pumped lasers.

Samples can be housed in the central experimental channel (CEC) (Ø142 mm), semispherical experimental channel (Ø300 mm), side and flyby channels (Ø100 mm) and in the "vault" (560×620 mm) as well. Irradiation can also be conducted in the lower reactor hall under semispherical experimental channel (SEC), where dimensions of irradiation samples are limited by the size of the hatch leading from the upper to the lower reactor hall (2×2 m) and hall height (2.5 m).

Main areas of studies

- Radiation resistance tests
- Study of nuclear pumped lasers

Main activities

Lifetime reactor operational characteristics are 778 pulses on prompt neutrons and 146 startups in the static mode with a new vessel. More than 2600 pulses had been generated before the vessel was replaced. At three former VIR modifications 2407 pulses were generated.

The reactor is planned to be shut down to replace control rod drives with unified ones, to replace CPS and then reach first criticality in the modernized reactor.

Contact person

LEONID GLUKHOV
Head of VIR-2M operation group
Tel (83130) 4-07-62
Fax (83130)2-87-06
otd04@expd.vniief.ru

GIR-2 REACTOR GAMMA SOURCE

GIR-2 research reactor is a fast pulse reactor with metal (U+Mo) core. The reactor is categorized as aperiodic self-quenching pulse reactor and designed for physical studies.

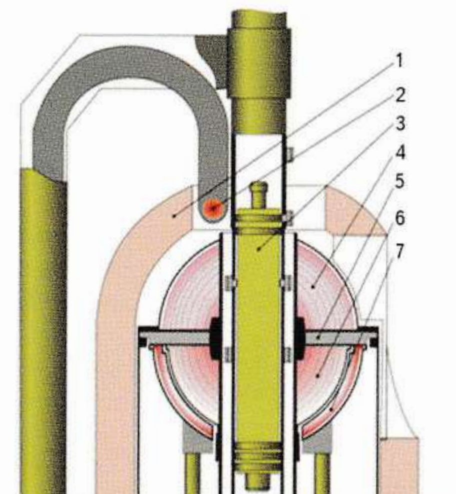
The first modification of GIR-1 reactor was operated from 1984 till 1988. Works on reaching first criticality in GIR-2 reactor were conducted from 02.04.1992 till 01.12.1992. Reactor was commissioned on 12.04.1993. Assigned life is 20 years (till 12.04.2013).

GIR-2 reactor has not been retrofitted.

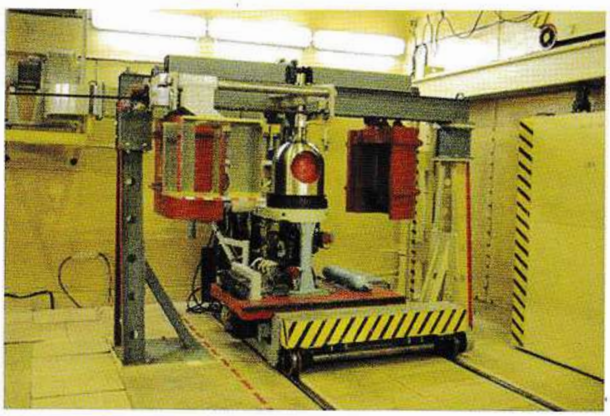
The main difference between GIR-2 and GIR-1 is fuel: GIR-1 uses non-alloyed HEU, and GIR-2 uses HEU-Mo alloy.

Spherical core consists of two hemispheres separated from each other by stainless steel membrane. Core diameter is 30 cm. Core material is HEU-Mo alloy (U enrichment is 36-90 % in ^{235}U and 9 mass % Mo). Fixed upper part of the core includes seven hemispherical layers, inner ones containing 90%-enriched ^{235}U and the outer one containing 36%-enriched ^{235}U. Lower part of the core consists of two movable units, namely: coarse adjustment unit and fine adjustment one. Coarse adjustment unit includes six 90%-enriched ^{235}U layers, and fine adjustment unit includes one 36%-enriched ^{235}U layer. To generate pulse an aluminum tube-shaped pulse unit is used.

GIR-2 salient feature is neutron reflector which is a 60 mm-thick walled cover surrounding the core. The reflector is made of homogenous mixture of polypropylene and cadmium oxide.



Schematic diagram of GIR-2 core:
1 – converter; 2 – neutron source; 3 – pulse unit; 4 – upper unit; 5 – membrane; 6 – coarse adjustment unit; 7 – fine adjustment unit



General view of GIR-2 reactor

GIR-2M main performance

Reflector .... Homogenous mixture of polypropylene and cadmium oxide

Static mode

Maximum power .... 1 kW

Power density per pulse .... Not limited

Pulse mode

Maximum power density .... 7 MJ

Minimum pulse half-width .... 300 μs

Power in a pulse peak .... Up to 23 GW

Pulse generation frequency is one pulse a day.

GIR-2 control room

It increases γ-yield of the facility and reduces disturbance from external devices. The reflector has spherical opening ("neutron window") designed for irradiating up to maximum neutron fluence.

GIR-2 can be operated in two modes:

- static mode – operation at steady-state power;
- pulse mode – pulses are generated on prompt neutrons.

Reactor core is cooled after the pulse by either natural convection or forced one produced by the fan.

GIR-2 experimental capabilities

GIR-2 reactor is used in radiation resistance tests of hardware, instrumentation, devices, equipment, electronic devices, quantum electronic devices and others. The reactor does not have experimental channels. Samples can be housed either on remote loading device or outside the core in any place of the reactor hall, 10×10×10 m.

MOP-K1 simulating reference neutron field complex was designed and qualified using GIR-2 reactor. This complex includes neutron fields in four points located on the same horizontal axis, which, in turn, goes through the core centre. Point 1 is directly on the core side surface inside the "neutron window", point 2K is on the opposite side on the outer surface of the converter, and points 3 and 4K are 500 mm from the core centre on the side of "neutron window" (point 3) and on the opposite side behind the convertor (point 4K), respectively.

GIR-2 irradiation characteristics at power density of 7 MJ

Total neutron fluence in the "neutron window" .... $1.1 \cdot 10^{14}$ cm^{-2}

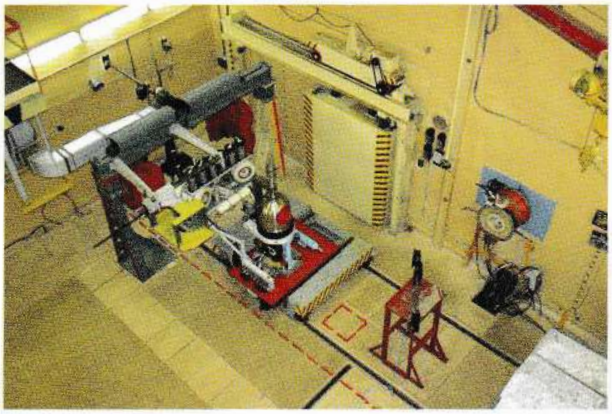
Neutron fluence (E > 0.1 MeV) in the "neutron window" .... $9.6 \cdot 10^{13}$ cm^{-2}

Maximum accompanying γ-radiation dose rate in the "neutron window" .... 400 Gy

Total neutron fluence on the reflector surface .... $2.3 \cdot 10^{13}$ cm^{-2}

Neutron fluence (E > 0.1 MeV) on the reflector surface .... $1.5 \cdot 10^{13}$ cm^{-2}

Maximum accompanying γ-radiation dose rate on the reflector surface .... 600 Gy



GIR-2 reactor near LIU-10M accelerator outlet

MOP-K complex is admitted for use as a reference facility as per GOST 8.105-80. It can reproduce differential neutron spectra within the range from 10^{-10} to 18 MeV and neutron fluence from 10^{7} to 10^{14} cm^{-2}.

Main areas of studies

- Radiation resistance tests
- Radiation safety studies

Main activities

Reactor operational parameters as of 31.12.2010 are 546 pulses on prompt neutrons. GIR-1 reactor generated about 350 pulses.

A series of irradiation tests were conducted to study ionization radiation impact on human being in emergencies. A mannequin simulating a human body with all internals was used as the object of study. Phantom material properties are the closest to human flesh. Mannequin was separated layer by layer, which made it possible to study ionization radiation impact in terms of various component percentage.

CPS is planned to be modernized.

Contact person

Mikhail Voinov, PhD (Phys&Math), Head of department, Head of GIR-2 operation group. Headed the development of GIR-1 and GIR-2 facilities.

MIKHAIL VOINOV
Head of GIR-2 operation group
Tel (83130) 4-07-62
Fax (83130) 2-87-06
otd04@expd.vniief.ru

CRITICAL FACILITY IKAR-S

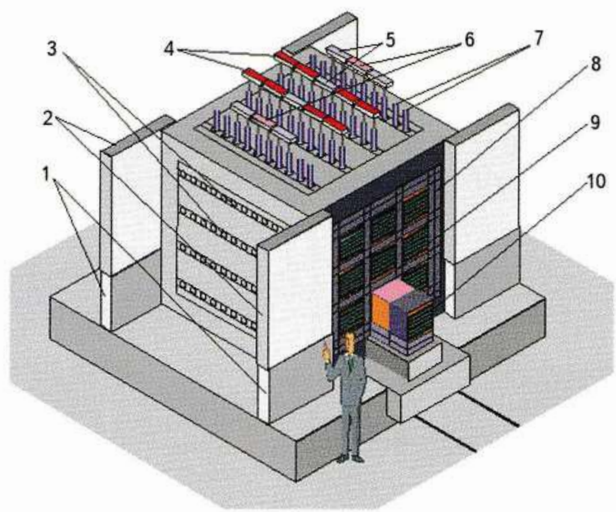
IKAR-S CF is designed for studying IKAR-500 reactor core that is channel-type aperiodic pulse reactor with power density of 500 MJ per pulse. Works on reaching first criticality in IKAR-S CF were carried out from 04.10.2004 till 30.11.2006. CF was commissioned on 01.12.2008.

Study of characteristics of multiplying systems, which simulate IKAR-500 core, is part of works on the development of nuclear and physical complex – physical model of continuous wave laser with transverse laser pumping. The complex includes IKAR-500 reactor and LM-16 laser module.

IKAR-500 core is a graphite matrix (a cube, 2400 mm on side) with nine walk-through cells, cross-section of 500×500 mm, which house reactor modules consisting of 2 sections each. Zirconium channels are installed on the side and top of graphite matrix (between the modules) to house reactor control members. Bottom central cell can house LM-16 laser module on the trolley instead of a reactor module. The core can be protected with shielding gate valves which significantly reduce ionization radiation.

IKAR-S CF which will be the basis of IKAR-500 reactor has the same design. Composition (graphite share, porosity, etc.) of sections will be changed. Each section consists of a set of alternative layers of graphite and U-Al dispersion fuel elements (72 pieces in a section).

IKAR-S designed life is not specified. After completion of the scheduled studies it is planned to build IKAR-500 reactor using the test bench.



IKAR-S CF diagram:
1 – lower gate valves; 2 – upper gate valves; 3 – horizontal channels; 4 – scram rod actuator drives; 5 – MC actuator drives; 6 – neutron source mechanisms; 7 – channels with neutron detectors; 8 – graphite assembly; 9 – multiplying system unit; 10 – system with multiplying media module

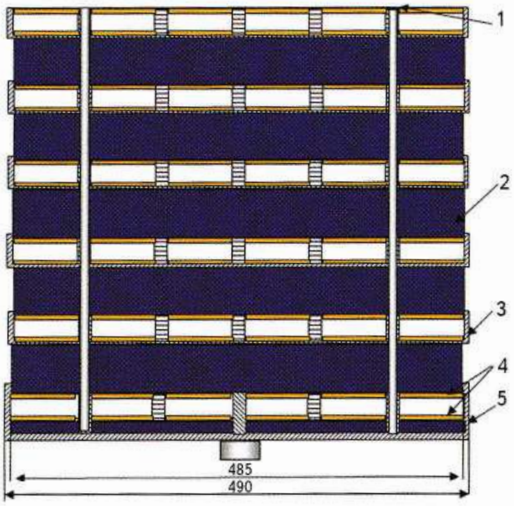
B_4C absorber rods are used as reactivity control members at CF. Every reactivity control member includes 2 absorber rods. Reactivity control members are categorized in four functional groups, namely: 2 groups of reactivity control rods and 2 groups of scram rods. KNK-4 and KNK-15 chambers are used as neutron detectors. CF design includes two IN-1 and IN-2 plutonium-beryllium neutron sources.

IKAR-S CF view on the side of reactor section loading

IKAR-S CF view on the side of potential loading of laser module

IKAR-S main performance

Dimensions of multiplying system	2400×2400×2400 mm
Type of multiplying system	18 sections in graphite matrix
Composition of multiplying system	A set of alternative layers of graphite and U-Al dispersion fuel elements in the structure made of E-125 zirconium-based alloy
Fuel type	Fuel core –U-Al dispersion (2.5 mass % U), enrichment in ^{235}U is 90 %, size of 5×60×900 mm; cladding – 0.5 mm-thick evacuated leaktight case made of E-125 (Zr-Nb) alloy
Overall dimensions of the unit	500×500×1200 mm
Maximum unit weight	500 kg
Maximum fuel load	960 kg
Maximum load in ^{235}U	24 kg
Moderator	Graphite
Reflector	Graphite (300 mm) – on sides; alternative layers of steel and polyethylene (385 mm) – gate valves on face surfaces
Maximum neutron flux in the multiplying system	$3.0 \cdot 10^{8}$ $cm^{-2} \cdot s^{-1}$
Thermal fission power	≤130 W
Multiplying system reactivity margin above the lower critical state	$\leq 0.5\ \beta_{eff}$
Total efficiency of scram rods (2 groups, 4 pieces each)	$\sim 32\ \beta_{eff}$-$\Delta\rho$
Total efficiency of reactivity control members (2 groups, 3 pieces each)	$\sim 24\ \beta_{eff}$-$\Delta\rho$
Multiplying system cooling	Natural heat removal



Reactor section cross-section diagram (72 fuel elements):
1 – pad; 2 – fuel element; 3 – frame with fuel elements and heat radiators; 4 – graphite; 5 – attachments

Main areas of studies

– Study of critical mass and kinetic characteristics of various multiplying systems which simulate IKAR-500 core

– Study of multiplying systems, which are graphite matrix housing sections made of a set of alternative layers of graphite and U-Al dispersion fuel elements.

Experimental capabilities

The following activities can be carried out at IKAR-S CF:

– selection of critical configurations of various multiplying systems;

– measurement of neutron multiplication and reactivity coefficients of multiplying systems;

– study of kinetic characteristics of multiplying systems;

– measurement of nuclear reaction spatial distribution;

– study of reactivity control member characteristics.

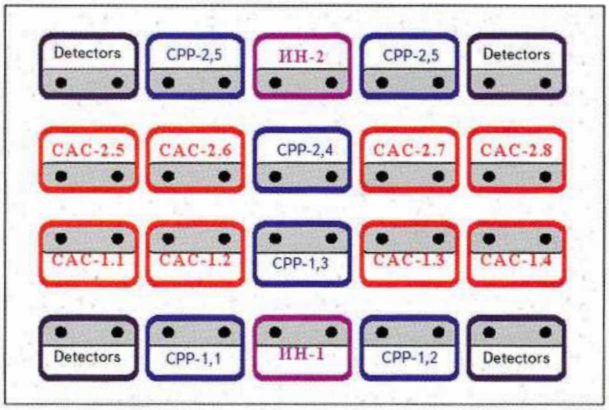
Main activities

IKAR-S CF was used to study various multiplying systems, which simulate IKAR-500 core.

As per the schedule CF is maintained and repaired four times a year.

Impact of nucleonic mockup of LM-16 laser module on the system reactivity has been studied.

Multiplying system section («reactor section»)



Layout of reactivity control members, neutron detectors and neutron sources:
CPP – manual control rod; reactivity control rod, ИН – neutron source, CAC – scram rod

Control room

Uranium-graphite fuel production technology for IKAR-500 reactor has been worked out to the extent that made it possible to use the technology in serial production. Fuel samples were successfully tested at BIGR reactor in operating conditions. More than 60 blocks have been manufactured. To provide negative

IKAR-500 temperature reactivity suppression the central module (2 sections) is supposed to be assembled from uranium-graphite blocks.

CF should reach first criticality again to make it possible to study multiplying systems with uranium-graphite central module.

After completion of planned tests IKAR-500 reactor will be built on the basis of CF. Development of reactor CPS is now underway.

Contact person

VLADIMIR TURUTOV
Head of IKAR-S CF operation group
Tel (83130) 4-07-62
Fax (83130) 2-87-06
otd04@expd.vniief.ru

Personalities

VALERY KRIVONOSOV
Leading engineer, IKAR-S project manager. Had been the Head of the laboratory of IKAR-S CF operation till 2011.

ANATOLY SINYANSKY
Chief Researcher, Dr. Sc. (Phys&Math). Heads studies in nuclear pumped lasers carried out at VNIIEF. Had been the Head of the department for IKAR-S CF and VIR-2M RR operation till 2011.

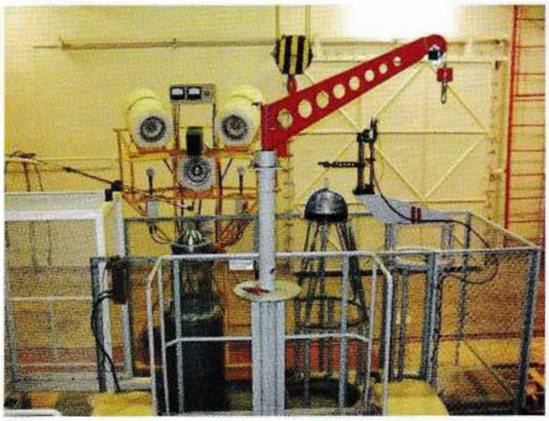
FAST NEUTRON PILE FKBN-2M

FKBN-2M CF – fast neutron pile – is designed for handling simple critical assemblies and multiplying systems. The present modification of CF reached first criticality 26.02-02.03.2001.

FKBN-2M has been repeatedly modernized; its designed life is not specified. It is planned to decommission the facility in the late 2012 to assemble units and systems of new FKBN-3 CF.

Unified sets of hemispherical parts made of fissionable and inert materials, which make it possible to assemble multiplying system without or with reflector of various thicknesses, are used in studies. First a lower part of multiplying system studied is assembled on the test bench table, which can move up and down. Then, an upper part is assembled on a carrier which can move horizontally. These preparations are carried out manually by the personnel. Parts of multiplying system are remotely moved closer to each other from the control room (the carrier is moved in working position and test bench plate is lifted). Emergency protection is provided by gravity drop of test bench table. Reactivity can be smoothly controlled at near-critical state by lifting/lowering control plug.

Central channel container is used for remote loading of samples, detectors or fission chambers into the central channel of the multiplying system. SPIN pneumatic transfer system is used for remote transfer of the container with a neutron source from the shielding unit to the multiplying system and back from it.



General view of FKBN-2M

Multiplying system is cooled at FKBN-2M CF by natural convection.

Experimental capabilities

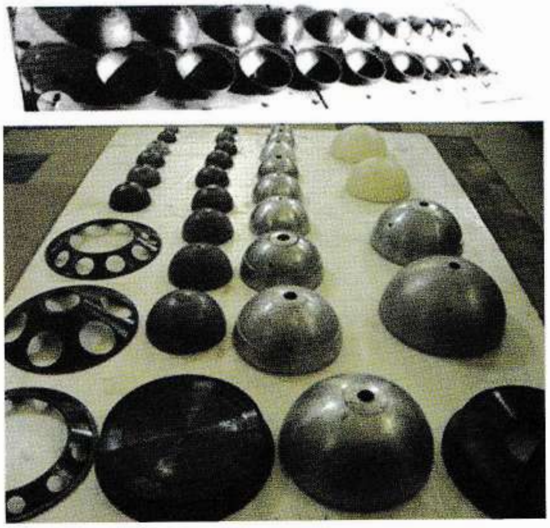
The following activities can be carried out at FKBN-2M CF:

- selection of critical configurations of various multiplying systems;
- measurement of neutron multiplication and reactivity coefficients of multiplying systems;

– study of kinetic characteristics of multiplying systems;

– measurement of nuclear reaction spatial distribution;

– obtainment of neutronic data on fission spectrum of multiplying system.



Unified sets of parts for multiplying system

Main areas of studies

Study of critical mass and kinetic characteristics of various simple multiplying systems.

International cooperation

Under ISTC projects and as per international contracts FKBN-2M CF was used to conduct various experiments related to the development of nuclear power engineering and specification of neutron constants with the support of specialists of the US National Laboratories (LANL, ORNL). Among the experiments are studies of neutronic characteristics of models of liquid salt blanket, cascade blanket for accelerator-driven system with ^{237}Np threshold fissionable material as well as studies of multiplying systems containing a central insert made of vanadium, lead, etc.

Experimental data for some multiplying systems studied are included in International Handbook of Evaluated Critical Safety Benchmark Experiments.

Based on FKBN-2M CF a full-scale simulator has been developed with the support of LANL specialists. Since it uses inert parts, the simulator can precisely simulate the processes of assembling and reaching first criticality by a multiplying system.

Main performance of FKBN-2M CF

Critical assembly type	Various assemblies, which consist of unified sets of hemispherical parts made of fissionable and inert materials
Neutron flux from the multiplying system	$\leq 1.5\cdot 10^{13}$ cm$^{-2}\cdot$s^{-1}
Reheat temperature of Ni-coated ^{235}U parts	$\leq$ 120 °C
Reheat temperature of other fissionable parts	$\leq$ 70 °C
Multiplying system reactivity margin above the lower critical state	$\leq 0.5\ \beta_{eff}$
Cooling of multiplying system	Natural heat removal
Maximum diameter of multiplying system	$\leq$ 1100 mm
Weight of upper and lower parts of the multiplying system apart	$\leq$ 1000 kg

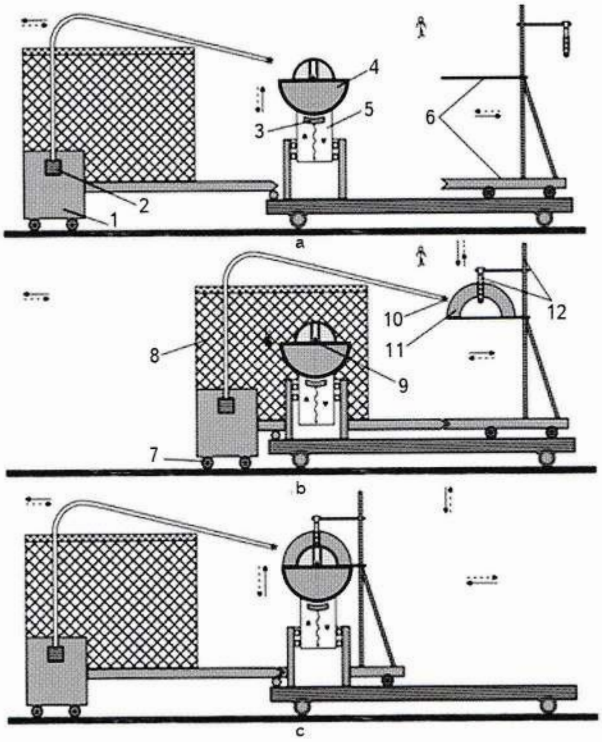
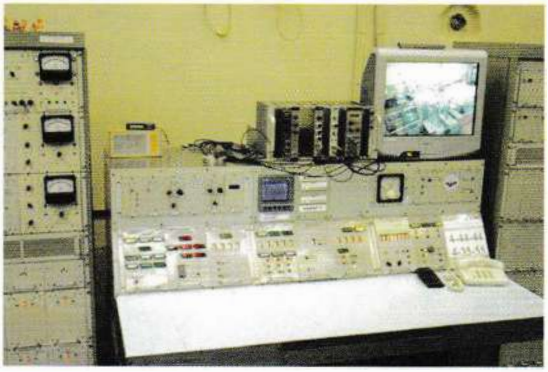
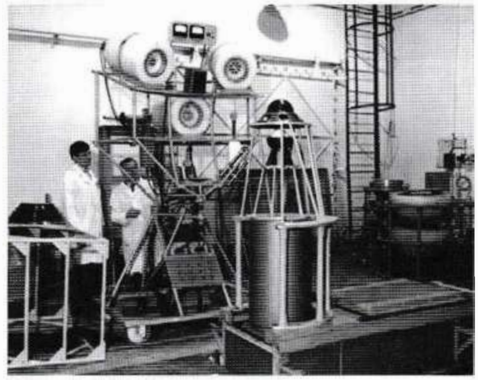


Diagram of multiplying system assembly at FKBN-2M CF: a – assembly of lower part of the multiplying system; b – assembly of upper part of the multiplying system; c – superposition of upper and lower parts of the multiplying system; 1 – shielding container; 2 – SPIN device; 3 – control plug; 4 – lower part of the multiplying system; 5 – movable table; 6 – carrier with a pad for the upper part of the multiplying system; 7 – SPIN trolley; 8 – metal enclosure; 9 – central neutron source; 10 – side neutron source; 11 – upper part of the multiplying system; 12 – central channel container mechanism



FKBN-2M control room

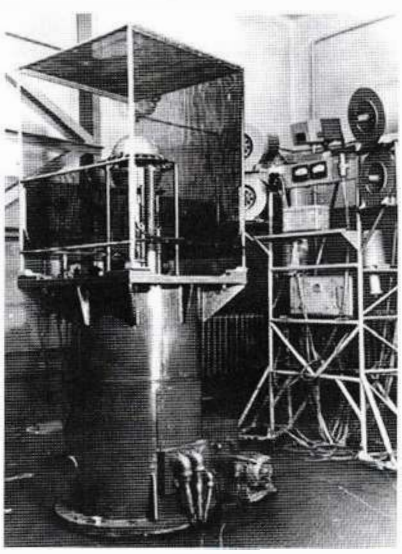


FKBN-2 facility

Main activities

More than 1000 multiplying systems have been studied using FKBN CF. About a half of them has almost reached critical state. The following fissionable materials have been studied: ^{235}U (90 %), ^{235}U (75 %), ^{235}U (36 %), ^{235}U (90 %)+Mo (9 mass %) alloy, ^{233}U, ^{239}Pu (88 %) in α- and δ-phases, ^{239}Pu (98 %) in δ-phase as well as solid simulators of ^{235}U(90 %) aqueous solutions. A number of multiplying systems had a core which contained two of the materials mentioned. Some 30 reflectors including water, polyethylene, copper, graphite, aluminum, iron, beryllium, beryllium oxide, ^{238}U, natural uranium, concrete, lead, tungsten, nickel, molybdenum, titanium, boron carbide and zirconium have been studied. Inert materials were placed outside the core, in the central chamber and between fissionable material layers as well.

As per the schedule CF is maintained and repaired four times a year.



FKBN-1 facility

Experimental and analytical studies of nucleonic characteristics of hemispherical assemblies made of metal Pu and HEU with ^{237}Np central inserts have been conducted to assess critical mass of "bare" Np sphere.

A new FKBN-3 test bench for critical assemblies is planned to be developed in the near future. It will make it possible to enhance safety of handling multiplying systems, improve repeatability of positions of CF movable parts and reduce errors in values specified in integral tests with multiplying systems. At this, the basic FKBN-2M-type design principles and operation procedure will remain the same.

Historical background

FKBN facility has been operated for more than 60 years now and had repeatedly been modernized. FKBN-2 CF has been operated since 1971. In 1976, CPS and table design of electromechanical test bench were modernized, and the facility titled FKBN-2M was commissioned.

In 1997, works at FKBN-2M CF were stopped. After improvement aimed at increasing facility safety and change in experiment procedures the activities on reaching first criticality at the CF were conducted (26.02–02.03.2001). On 15.05.2001 FKBN-2M CF was commissioned.

Contact person

ALEXANDER PANIN
Head of FKBN-2M operation group
Tel (83130) 4-07-62
Fax (83130) 2-87-06
otd04@expd.vniief.ru