3.12. RESEARCH INSTITUTE OF INSTRUMENTS

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Federal State Unitary Enterprise "Research Institute of Instruments" (NIIP) was formed on March 28, 1956 as a center for testing a small nuclear reactor for airplane and rocket propulsion systems.

In 1960 it was named ILVAR (Testing Laboratory of High-Temperature Nuclear Reactors). ILVAR was assigned to testing such items as an airborne power station, a thermionic power system and a direct-conversion power system.

NIIP complex

In 1966 ILVAR was renamed LIP (Laboratory of Measuring Instruments). Later, the International Center of Radiation Tests (MTsRI) was established on the LIP basis. The center was primarily involved in experimental research on and development tests of nuclear propulsion systems, development of and research into the efficiency of airplane and spacecraft shielding, and research into properties of absorber and shielding materials.

In 1972 the Laboratory of Measuring Instruments was renamed the Research Institute of Instruments (NIIP). Vladimir Rogov, Dr. Sc. (Tech.), Professor, Honored Worker of Science and Technology of the Russian Federation and a veteran of the Russian nuclear weapons complex, was appointed the Director of NIIP. Yury Tuturov, Dr. Sc. (Phys.&Math.), Professor and a USSR State Prize winner, was appointed NIIP's Scientific Director.

In 2001 NIIP was given the status of a federal state unitary enterprise while remaining assigned to the same set of major tasks: experimental research on and tests of nuclear power and propulsion systems and research into the efficiency of airplane and spacecraft shielding.

A.M. CHLENOV,
Director of NIIP

D.I. MARKITAN,
Chief Engineer of NIIP

A.M. Chlenov, Cand. Sc. (Tech.), and D.I. Markitan have been respectively NIIP's Director and Chief Engineer since 2003.

NIIP nowadays is a center for radiation tests of electronic and radio-electronic items. The recognition of NIIP's scientific and technological advances was the formation on the NIIP basis of Russia's head organization on radiation stability of radio-electronic components and radio materials, radiation tests of accessories and materials for electronics of nuclear power plants and nuclear propulsion systems, and dosimetry of high ionizing radiation fluxes.

Under the Federal Law on Use of Atomic Energy, the Institute has the status of an operator in the field of atomic energy use.

Main areas of studies

– Research on the radiation stability of electronic and radio-electronic items, and determination of reliability and applicability criteria.

– Development of physico-mathematical models to predict radiation-induced variations in the parameters of items under different intensities of radiation effects, temperatures and electrical modes.

– Development, establishment and certification of procedures to measure characteristics of ionizing radiation fields in nuclear power, isotope and electrophysical facilities.

- Certification and certification tests of items to be used in conditions of effects from ionizing radiation, and mechanical (including shock), thermal and climatic loads.
- Assessment of residual life to extend the operating time of electrical components and cables used at NPPs.
- Production of monocrystalline silicon.
- Irradiation sterilization of medical items and food products.

Historically, the complex of NIIP's facilities comprised up to 12 nuclear reactors for a variety of applications, including:

- IRV-M1, an stationary water-cooled water-moderated pool-type nuclear research reactor;
- BARS-2, BARS-3, BARS-4 and TIBR-1M, solid-fuel self-quenching pulse nuclear research reactors with natural air cooling;
- IIN-ZM, a self-quenching pulse solution nuclear research reactor with natural air cooling;
- VVRL-02 and VVRL-03, two transportable pressure-vessel water-cooled water-moderated stationary thermal-neutron nuclear research reactors (N=100 kW) with air cooling of the primary coolant;
- BES No.16, BES No.25, BES No.32 and BES No.57, four stationary fast-neutron space-purpose nuclear power reactors (N=100 kW) with a liquid-metal coolant (Na-K eutectics).

NIIP operates the BARS-4, a two-core pulse reactor, and has under construction the IRV-M2 stationary reactor.

The rest of the reactor facilities have been decommissioned and deregistered.

Apart from the reactors, NIIP includes other unique facilities for radiation tests (accelerators, isotopic radiators), mechanical tests (vibration and shock benches), and climatic and electromagnetic tests (pulse, static and variable fields).

Nuclear research facilities of NIIP

	BARS-4	IRV-M1 (IRV-M2)
Thermal power, kW	≤10,00	4 000,00
First criticality	1994	1975
Status	In operation	Construction
Operating time (as of 2012), years	18	16

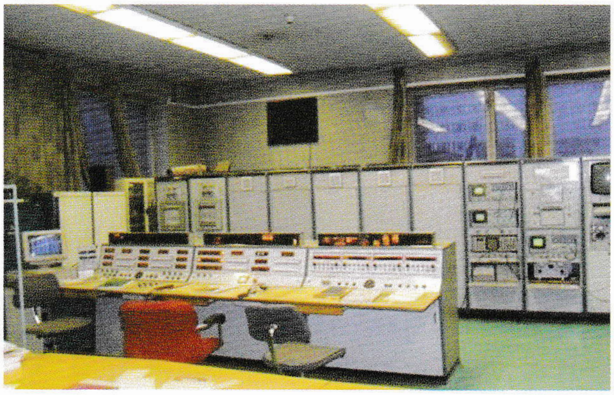
BARS-4 FAST-NEUTRON (TWO-CORE) PULSE REACTOR

The BARS-4 pulse reactor is an aperiodic self-quenching fast-neutron two-core reactor representing a source of neutrons with a spectrum close to the fission spectrum. The BARS-4 reached first criticality on 03.06.1980, and its power startup took place on 03.04.1984.

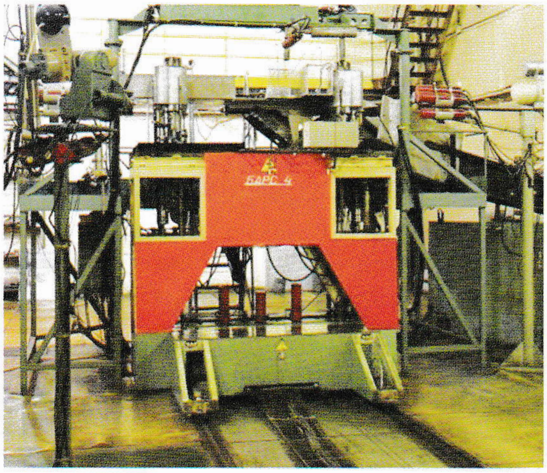
The reactor has the following major components: two identical solid-fuel cores based on a fixed and on a movable support plate, air blocks of the CPS actuators, control and protection working members, and neutron source drives. The reactor is deployed on a truck with a drive, traveling on a rail track from the biological shielding area (the parking area) to the test bench area. The distance between the cores may vary between 0.333 and 1.5 m.

The BARS-4 reactor is operated as follows: in response to the respective command from the control room the reactor moves from the biological shielding area to the rack with samples in the test bench area for irradiation of samples by the generated pulse.

After the experiments are over, the reactor truck travels back to the parking area, where both cores are placed beneath the biological shielding, which decreases the core radiation level by a factor of about 100. The parking area opening has a 1000 mm thick concrete shielding gate, which decreases the γ-radiation level further by a factor of about 700. This makes it possible to prepare the experimental devices for another experiment on the rack without personnel exposure to above the permissible level.



BARS-4 reactor control room



BARS-4 two-core pulse nuclear reactor

Main performance of the BARS-4 reactor

Number of fissions per pulse	$(0.7\ldots1.0)\cdot10^{17}$
Fluence of neutrons per pulse ($E>0.1$ MeV)	
central hole	Up to $10\cdot10^{13}$ cm^{-2}
core surface	Up to $1\cdot10^{13}$ cm^{-2}
γ-radiation exposure dose per pulse	
central hole	$(100\ldots500)\cdot10^{3}$ R
core surface	$(10\ldots30)\cdot10^{3}$ R
Average energy of neutrons	1.4 MeV
Pulse duration	80 μs
Central hole diameter	60 mm
Static-mode neutron flux in the central hole	$(1\ldots18)\cdot10^{10}$ cm$^{-2}\cdot$s^{-1}

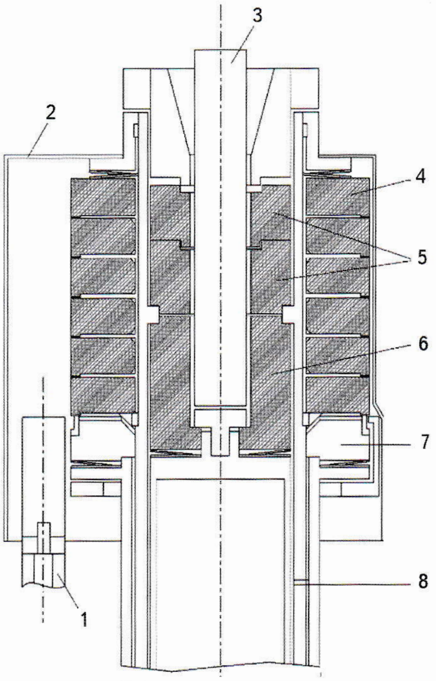


Diagram of the BARS-4 core:
1 – disks; 2 – inserts; 3 – safety block; 4 – regulation block; 5 – central support tube; 6 – pulse rod; 7 – boron sheath; 8 – central hole

The design of the BARS-4 cores features:

– small dimensions of the cores with a central hole (Ø 60 mm);

– no efficient reflector and availability of a boron shield;

– short life of neutrons ($1.5\cdot10^{-8}$ s);

– no moderator in the core;

– a hard spectrum of neutrons (spectrum of fissions);

– the lowest possible number of elements that vary the reactor reactivity.

The core is cooled after the pulse generation by natural air convection.

Experimental capabilities of the BARS-4

Objects to be irradiated may be positioned on a table, on the sample fastening grid (near and between the cores) and in canisters that are lowered into the central channels of the core using the mechanism for remote insertion and rapid withdrawal of samples from the cores.

All samples are secured rigidly with the aid of a bolted joint that prevents them from moving spontaneously relative to the cores. The maximum influence of samples on the reactor reactivity is +3.0 β_{eff}. Nuclear safety is ensured with any geometry and any positions of samples relative to each other and the reactor.

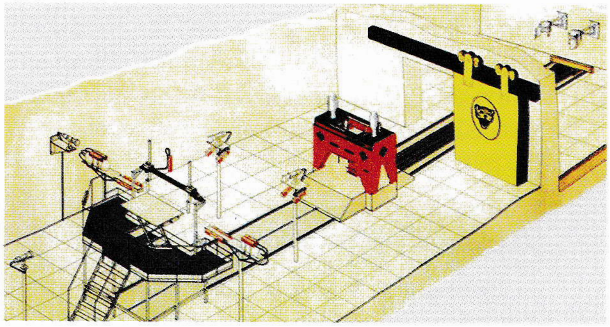
The test frequency is not more than two per day. The materials and fluids used in experiments should not have aggressive components and affect the corrosion resistance of the core structural materials and fuel elements.

Main areas of studies

– Experimental justification of the radiation stability of electronic and radio-electronic items.

– Experimental determination of radiation stability, reliability and applicability criteria of items.

– Development tests of physico-mathematical models to predict radiation-induced variations in the parameters of items at different intensities of radiation effects, temperatures and electrical modes.



BARS-4 reactor process area

– Certification and certification tests of items to be used in conditions of effects from ionizing radiation, and mechanical (including shock), thermal and climatic loads.

– Determination of residual life for extending the operating time of electrical components and cables used at NPPs.

– Irradiation sterilization of medical items and food products.

Main activities

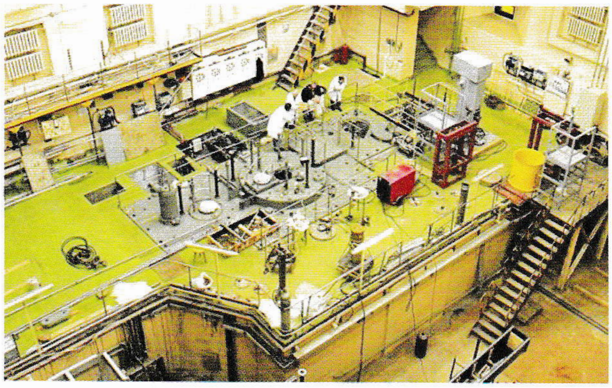
The reactor utilization factor in 2011 was 0.800.

IRV-M2 POOL-TYPE RESEARCH REACTOR

The IRV-M2 research reactor is being built under a NIKIET project in place of the IRV-M1 reactor, a water-cooled water-moderated pool-type reactor that was used for research into radiation stability of materials, electronics and electrical components.

The IRV-M1 reactor reached first criticality on 28.12.1974, and its power startup took place on 15.10.1975.

In 1991 the reactor was shut down to have its major systems checked up. Simultaneously, the efficiency of the reactor's experimental



IRV-M2 reactor hall

capabilities was analyzed and ways to improve the reactor economics were searched for.

The results of the reactor checkup led in 1992 to a decision to give the reactor a major retrofit for the purpose of:

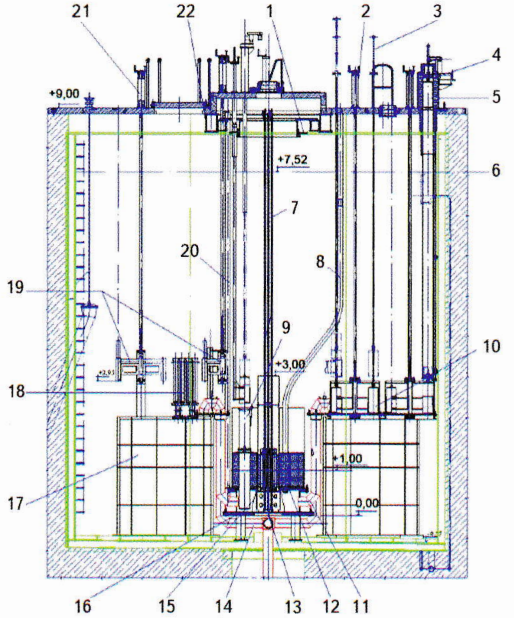
– improving safety through redesign and adoption of novel scheme concepts;

– increasing the neutron flux and the reactor power;

– improving the economics of the reactor thanks to extending the scope of commercial operations.

The IRV-M1 retrofit project was approved in 2000. NIKIET was the chief designer and developer of the reactor retrofit project. Practically all reactor systems were retrofitted so the reactor facility was renamed the IRV-M2 and given the status "under construction".

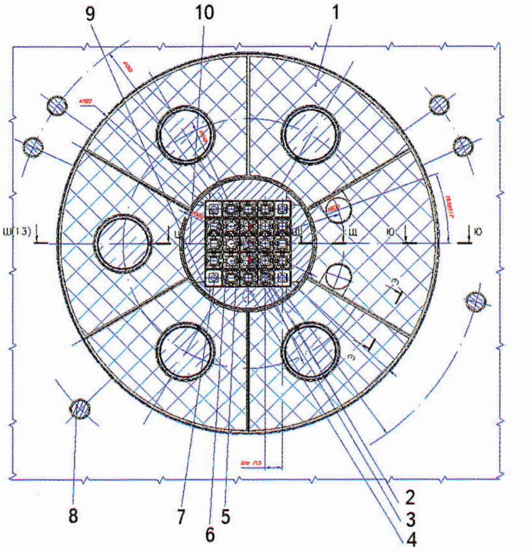
The reactor vessel is formed by two concentric shells with a common base. The core with the beryllium reflector segments is installed in the inner shell. A graphite reflector with vertical experimental channels is installed in the outer shell.



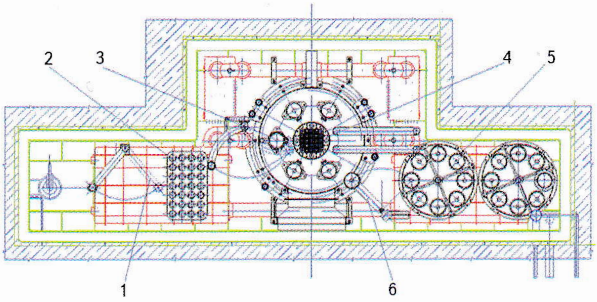
Vertical section of the IRV-M2 reactor:
1 – rotary ring; 2 – carousel drive; 3 – bar; 4 – container; 5 – canister; 6 – water level; 7 – CPS channel; 8 – vertical experimental hole; 9 – silicon doping hole; 10 – carousel; 11 – discharge pipeline; 12 – reflector; 13 – core; 14 – supply pipeline; 15 – header; 16 – support; 17 – retaining tank; 18 – FA storage; 19 – rotary cantilever; 20 – IC hole; 21 – cantilever drive; 22 – support beam

Main performance of the IRV-M2 facility

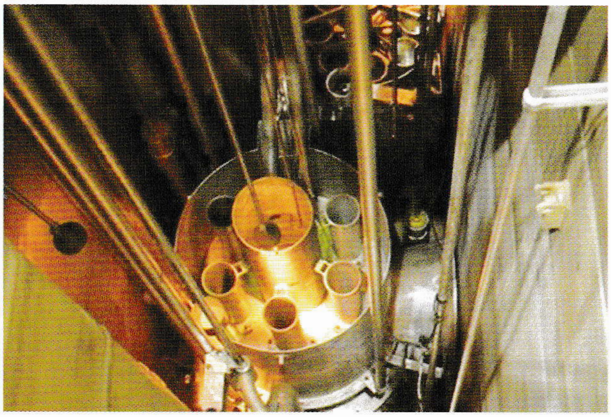
Power	4.0 MW
Number of IRT-2M fuel assemblies	21
Neutron flux:	
in silicon irradiation channels:	
thermal neutrons	$0.56\cdot10^{13}\ \text{cm}^{-2}\cdot\text{c}^{-1}$
fast neutrons	$0.057\cdot10^{13}\ \text{cm}^{-2}\cdot\text{c}^{-1}$
in dry vertical channels:	
thermal neutrons	$1.4\cdot10^{13}\ \text{cm}^{-2}\cdot\text{s}^{-1}$
fast neutrons	$0.2\cdot10^{13}\ \text{cm}^{-2}\cdot\text{s}^{-1}$
Coolant temperature:	
at core inlet	50 °C
at core outlet	60 °C
Reactor pool surface area	15 m^2
Pool water volume	112 m^3



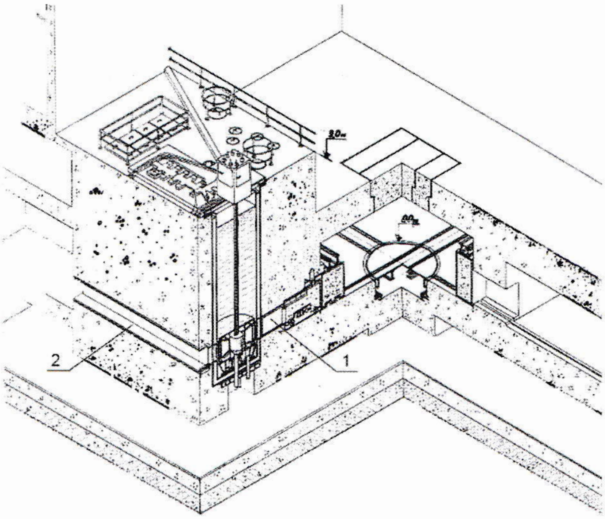
Cross-section of the core and the reflector:
1 – graphite block; 2 – scram rod; 3 – automatic regulation rod; 4 – shim rod; 5 – four-tube FA; 6 – three-tube FA; 7 – aluminum block, 8 – ionization chamber; 9 – displacer; 10 – beryllium block



Cross-section of the IRV-M2 reactor:
1 – core; 2 – carousel with canisters for silicon; 3, 4 – rotary cantilever, 5 – spent fuel storage, 6 – silicon doping chambers



Experimental channels of the IRV-M2 reactor



The IRV-M2 reactor position in civil structures:
1 – end niche, 2 – horizontal hole

IRV-M2 reactor core and reflector grid

The reactor vessel is merged into the pool water. The reactor pool is a tank with double leak-tight walls of the SAV-1 aluminum alloy. There are drain tubes led out of the space between the tank walls to monitor the pool tightness.

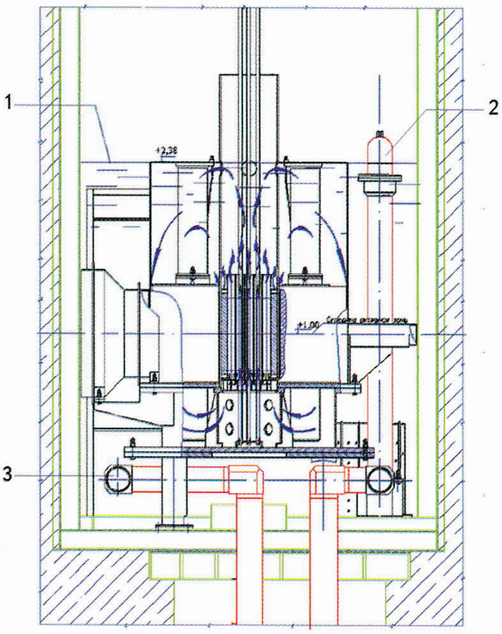
The design of the reactor vessel with the primary circuit piping inside the pool makes it possible to achieve natural circulation with the in-vessel water flow rate and amount sufficient to remove residual heat during blackout, depressurization or a break of the primary circuit pipelines both inside and outside the pool, as well as during pool loss of leak-tightness.

At the top, the pool is covered with shielding plates, which enables personnel to serve the experimental devices during reactor power operations.

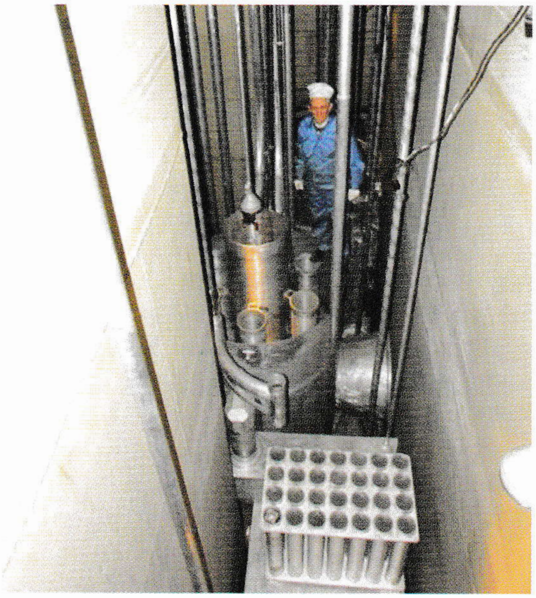
Experimental capabilities of the IRV-M2

For experiments the reactor includes:

- horizontal experimental channels:
  - one tangential hole of (1200×1200) mm;
  - one end hole of (1200×1600) mm;



Flowchart of the emergency core cooling:
1 – minimum water level during pipeline break outside the reactor pool; 2 – supply pipeline; 3 – discharge pipeline



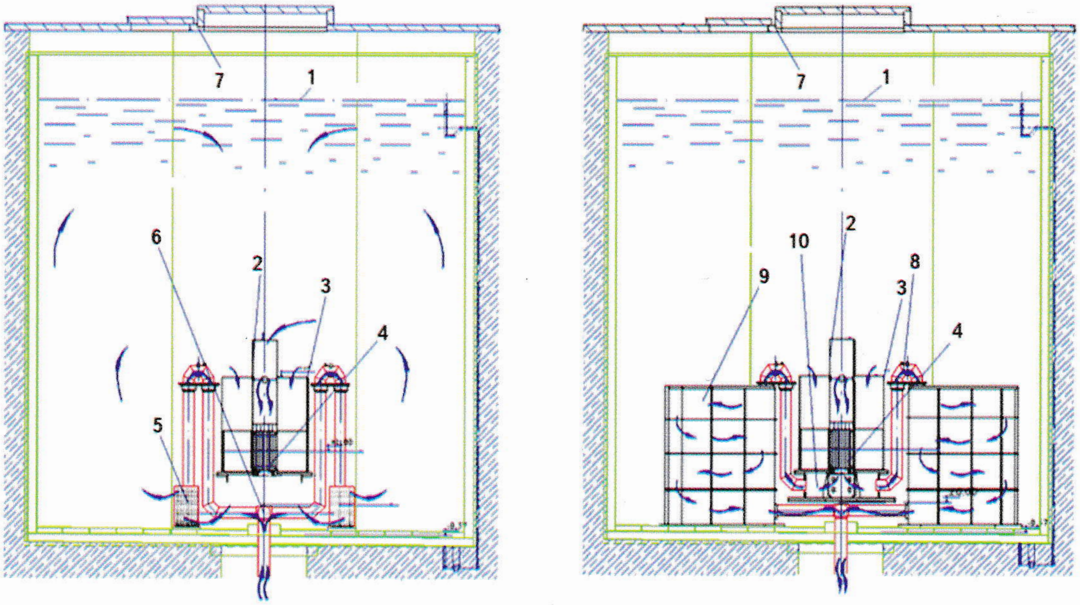
IRV-M2 reactor design inside the pool

- vertical experimental channels:
  - five Si ingot irradiation channels of the diameter up to 205 mm;
  - two dry channels of the diameter 100 mm.

The exeprimental channels of the reactor enable:

- experimental justification of radiation stability for electronic and radio-electronic items;
- experimental determination of radiation stability, reliability and applicability criteria for items;
- development tests of physico-mathematical models to predict radiation-induced variations in the parameters of items at different intensities of radiation effects, temperatures and electrical modes;
- certification and certification tests of items to be used in conditions of effects from ionizing radiation, and mechanical (including shock), thermal and climatic loads;
- development, establishment and certification of techniques to measure characteristics of ionizing radiation fields for nuclear power, isotope and electrophysical facilities;
- determination of residual life for extending the operating time of electrical components and cables used at NPPs;
- production of monocrystalline silicon;
- irradiation sterilization of medical items and food products.

One of the horizontal channels can be used for neutron-capture therapy activities.



Pressure portion **Outlet portion**

Flowchart of the core cooling:
1 – water level; 2 – inner shell; 3 – outer shell; 4 – core; 5 – perforated tank; 6 – supply pipeline; 7 – upper ceiling; 8 – discharge pipeline; 9 – retaining tank; 10 – header

Main areas of studies

Research into radiation effects in materials and electronic components caused by ionizing radiation.

Research into ionizing radiation transport in a substance.

Development of techniques to diagnose characteristics of different ionizing radiation fields across a broad range of intensities and energies.

Development of techniques for radiation and reliability qualification tests of electronics on simulators.

Development of techniques to predict serviceability of radio-electronic components and units at different intensities and lengths of radiation loads and different temperatures and electrical modes.

Main activities

Adjustment and preliminary tests of separate silicon doping control system components.

Adjustment operations using earlier developed programs and preliminary test procedures for the IRV-M2 reactor control and protection system hardware.

Contact person

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