Research reactors in Russia. Status and prospects for reducing the fuel enrichment

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The Russian Government mandated the ROSATOM to negotiate with the U.S. Department of Energy signing of an implementing agreement "concerning cooperation in research into feasibility of conversion of the Russian research reactors to use low enriched uranium fuel." Related directive No 1919-r of October 30, 2010, was signed by Russian Chairman of the Government Vladimir Putin.

ROSATOM explained that the matter is the financing of a feasibility study of conversion of the Russian research reactors to use fuel of lower enrichment. The negotiations with the U.S. on this issue are planned to hold during a visit of Deputy Secretary of Energy Daniel Poneman to Moscow in December.

The Russian-American cooperation in this area is carried out in frames of the Reduced Enrichment for Research and Test Reactors Program. The program is aimed at reducing a potential threat of the use of radioactive materials for terrorist purposes and provides for conversion of research reactors to fuel enriched up to 20% with uranium-235.

The Russian Academy of Sciences and the U.S. National Academies formed a joint Committee to support the conversion of research reactors from highly enriched uranium to low enriched uranium fuel.

Russian Research Reactors

Kurchatov Institute (Moscow)

IR-8
OR
Argus

RIAR (Dimitrovgrad)

MIR-M1
SM-3
RBT-10/2
RBT-6

Moscow Engineering and Physics Institute

IRT

St. Petersburg Institute of Nuclear Physics

WWR-M

Reactor Materials Institute (Zarechny)

IVV-2M

Karpov Institute of Physics and Chemistry (Obninsk)

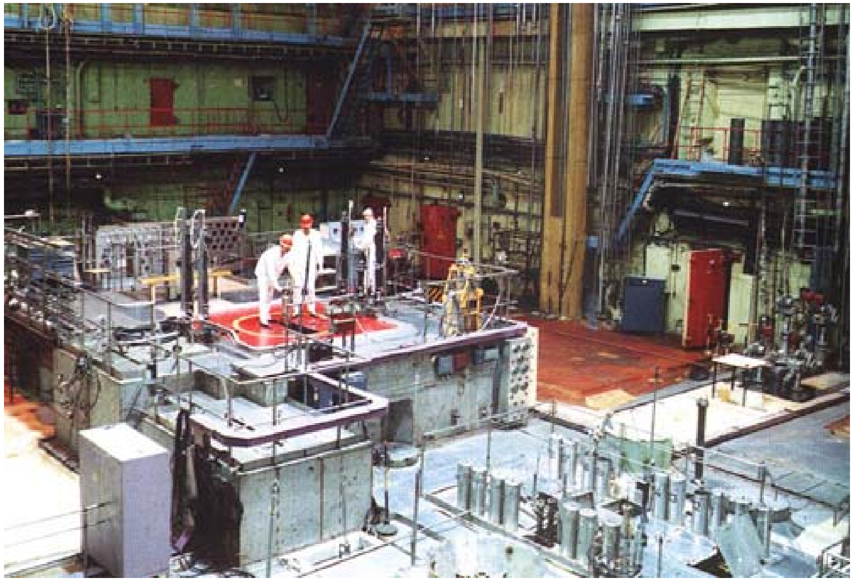
WWR-Ts

Scientific Research Institute of Nuclear Physics (Tomsk)

IRT-T

RIAR (Dimitrovgrad)

High-Flux Research Reactor SM
Year starting: 1961
Type: Pressure vessel
Therm Power Steady: 100 MW
Max thermal neutron flux: 5E15 (n/cm^2-s)
Max fast neutron flux: 2E15 (n/cm^2-s)
90% enriched uranium fuel

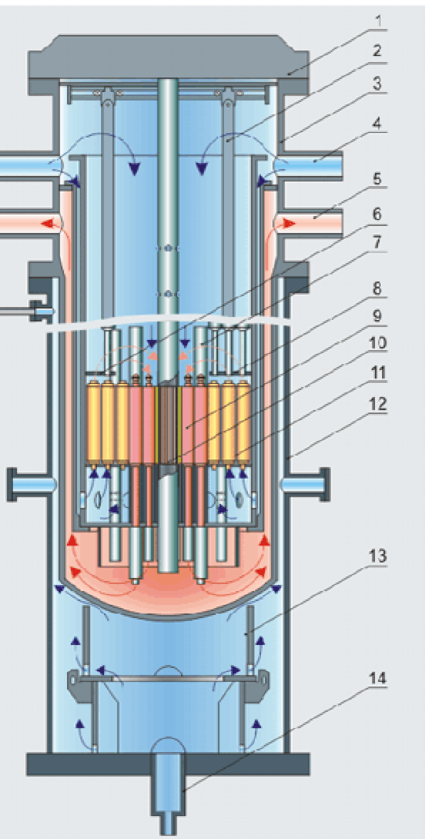


The high-flux research reactor SM is designed for experimental irradiation of reactor materials samples under the set conditions and studying the mechanisms of changes in different materials under irradiation. It is also used to produce a wide range of radionuclides, including far transuranics, to perform research in the field of nuclear physics. The idea of achieving high thermal neutron flux density in a moderating trap located in the core centre with hard neutron spectrum was implemented for the first time in the SM design (thermal neutron flux density achieves $5 \cdot 10^{15}$ n/cm^2-s, fast neutron flux density achieves $2 \cdot 10^{15}$ n/cm^2-s).

RIAR (Dimitrovgrad)

High-Flux Research Reactor SM

1. Зазор между Be-блоками и между пластинами Be-блоков δ = 1,5 мм;
2. Ячейка вертикального канала;
3. Поглотитель компенсирующего органа (КО) ∅ = 69 мм, h = 360 мм, n… = 52 шт.;
4. Тепловыделяющая сборка активной зоны ∅ = 69,5 мм, h = 350 мм;
5. Поглотитель автоматического регулятора ∅ = 63 мм, h = 360 мм, n… = 76 шт.;
6. Be-блок n = 44 шт., h = 500 мм;
7. Ячейка разгрузочной площадки;
8. Корпус активной зоны ∅ = 1250 мм, h = 1485 мм;
9. Разделитель ∅ = 1230×10 мм, h = 4758 мм;
10. Экран ∅ = 1300×10 мм, h = 5966 мм;
11. Корпус новый реактора ∅ = 1460×30 мм, h = 7333 мм;
12. Корпус старый реактора ∅ = 1572×36 мм, h = 7006 мм;
13. Труба горизонтального канала № 1 Æ = 115 мм;
14. Кадмиевая пластина разгрузочной площадки;
15. Ячейка ампульного канала Æ = 72 мм;
16. Be - вкладыш;
17. Be - сепаратор центрального блока трансурановых мишеней (ЦБТМ) Æ = 93 мм, h = 166,5 мм, отверстия под мишени Æ = 12,8 мм, n = 27 шт.,
18. Поглотитель аварийной защиты Æ = 20 мм, h = 360 мм, n… = 11 шт.;
19. Поглотитель центрального компенсирующего органа (ЦКО) Æ = 104 мм, h = 360 мм, n… = 29 шт.;
20. Труба горизонтального канала № 2 Æ = 100 мм;
21. Зазор межкорпусного пространства δ = 20 мм;
22. Всасывающая полость δ = 50 мм;
23. Полость нагнетания δ = 25 мм;

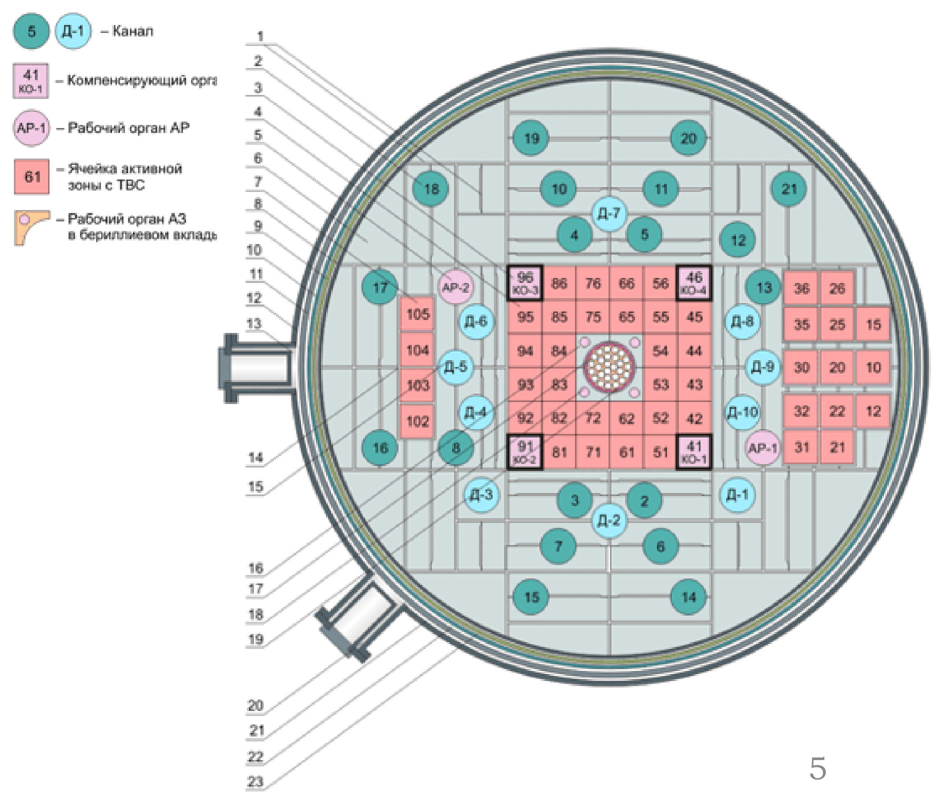


Основные технические характеристики реактора СМ-3

Высота активной зоны реактора СМ 350 мм,
высота бокового отражателя 500 мм.
В реактор могут устанавливаться ампульные устройства и каналы облучения:
– в отражатель до 30 (диаметр до 70 мм);
– в центральную высокопоточную ловушку до 27 (10 мм) или один канал (90 мм);
– в активную зону до 24 каналов (10мм)

Схема реактора СМ-3

1 - крышка;
2 - механизм перегрузки;
3 - корпус СМ-3;
4 - входной патрубок;
5 - выходной патрубок;
6 - малая разгрузочная площадка;
7 - труба КО;
8 - большая разгрузочная площадка;
9 - ТВС;
10 - центральная высокопоточная полость;
11 - бериллиевый отражатель;
12 - корпус СМ-2;
13 - тепловая защита СМ-2;
14 - входной патрубок системы охлаждения межкорпусного пространства



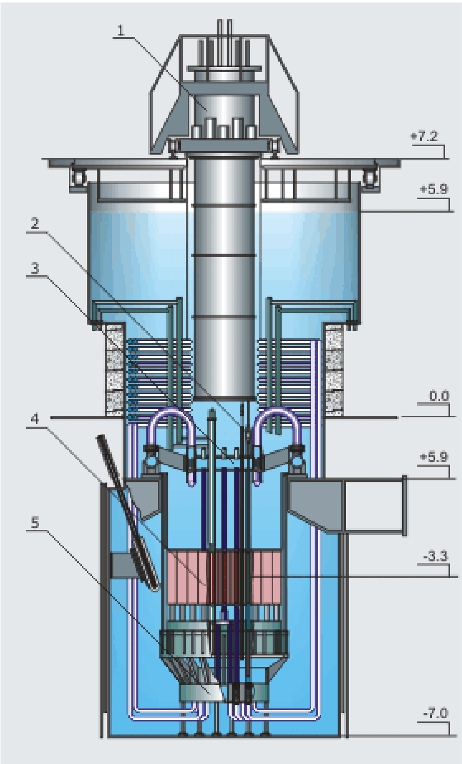
RIAR (Dimitrovgrad)

Loop-Type Research Reactor MIR-M1
Year starting: 1964
Type: Pool/Channels
Therm Power Steady: 100 MW
Max thermal neutron flux: 5E14 (n/cm^2-s)
Max fast neutron flux: 3E14 (n/cm^2-s)
90% enriched uranium fuel

The loop-type research reactor MIR is designed mainly for testing fuel elements, fuel assemblies and other core components of different types of operating and promising nuclear power reactors. Tests and experiments simulate both standard (steady-state and transient) conditions and the majority of the design-basis accidents. Tests can be carried out in several (up to 10) channels at a time, the neutron flux density being 4-5 times different from the average one.

RIAR (Dimitrovgrad)

Loop-Type Research Reactor MIR-M1



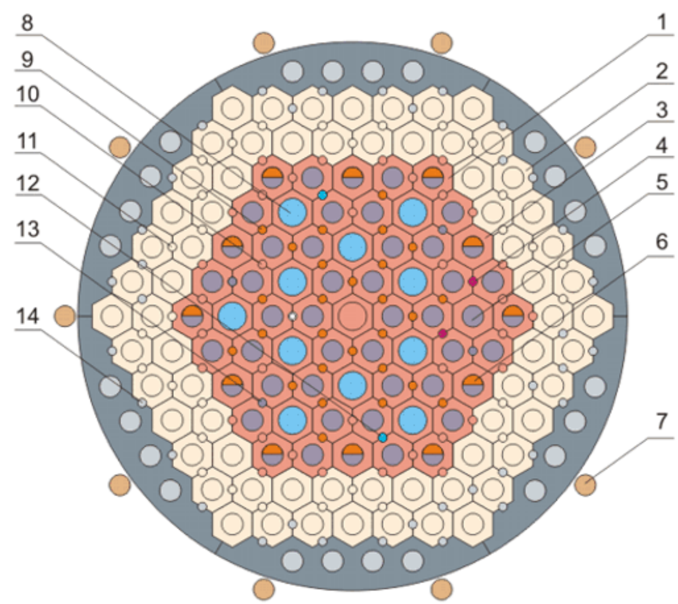
Характеристики петлевых установок реактора МИР:

Параметр	Петлевые установки				
	ПВ-1 ПВ-2	ПВК-1 ПВК-2	ПВП-1	ПВП-2	ПГ-1
Теплоноситель	Вода	Вода, кипящая вода	Вода, пар	Вода, пар	Гелий или смесь газов
Температура теплоносителя на выходе из канала, С°	340	340	500	500	1000*
Расход теплоносителя в канале, т/ч	16	14	0,675	1,0	—
Допускаемая удельная активность продуктов деления в теплоносителя, Ки/кг	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	1,0	1,0
Давление, МПа	18	18	8,5	20	20
Максимальная тепловая мощность, кВт	2000	2000	2000	2000	200
Число каналов	По 2	По 2	1	1	1

Схема реактора МИР

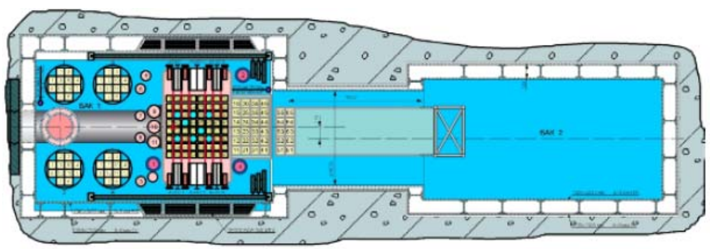
1 – тележка приводов СУЗ
2 – компенсирующий стержень
3 – водяной коллектор
4 – активная зона
5 – трубная решетка

1 – Be - блок активной зоны
2 – Be - блок отражателя
3 – Be - блок петлевого канала
4 – Стержень АР
5 – Рабочий канал
6 – Канал с догрузкой
7 – Ионизационная камера
8 – Петлевой канал
9 – Стержень АЗ-КС
10 – Be - пробка активной зоны
11 – Be - пробка отражателя
12 – труба СУЗ
13 – труба СУЗ с заглушкой
14 – Al - пробка

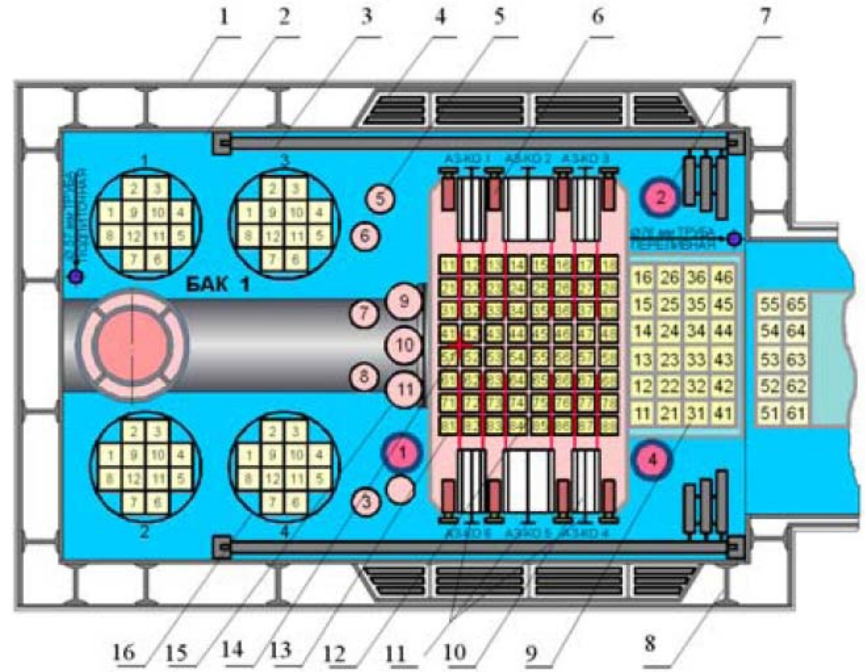


RIAR (Dimitrovgrad)

Pool-Type Reactor RBT-6
Year starting: 1975
Type: Pool
Therm Power Steady: 6 MW
Max thermal neutron flux: 2.2E14 (n/cm^2-s)
Max fast neutron flux: 5.7E13 (n/cm^2-s)
Uses spent fuel from the SM reactor



The reactor is designed to perform long-term experiments under stable parameters that do not require rapid achievement of neutron fluence. The peculiar feature of this reactor is that it uses fuel assemblies spent in the SM reactor. High content of ^{235}U in such fuel assemblies provides neutron flux density of 10^{13} – 10^{14} sm^{-2}·s^{-1}; low rate of the reactivity decrease during the operation is related to the presence of gradually burning ^{149}Sm accumulated in the SM reactor.
Pool reactor consists of two vertical rectangular cross-section tank of similar design, interconnected by jumper ∅ 1000 mm. The core is placed in the tank number 1.



1 – наружная поверхность бака;
2 – внутренняя поверхность бака;
3 – основная боковая защита;
4 – дополнительная боковая защита;
5 – ионизационная камера без экрана;
6 – стойка АЗ-КО;
7 – защитный экран ионизационной камеры;
8 – двутавр; 9 – ячейки под ампулы облучательного устройства "Корпус"; 10 – плита съемная;
11 - секции АЗ-КО; 12 – канал облучения (зонный);
13 – тепловыделяющая сборка; 14 – орган АР;
15 – канал облучения (периферийный);
16 – кассета для загрузки отработавших ТВС.

Расположение оборудования в баке № 1 ИЯУ РБТ-6

RIAR (Dimitrovgrad)

Pool-Type Reactor RBT-6

Active zone RBT-6 is formed from the spent SM fuel assemblies with burnup less than 47% and represents the correct square prism from the base of 615 mm.
Feature of the RBT-6 is the possibility of long continuous work with little initial reactivity margin, as accumulated in the spent fuel rods, samarium-149 plays the role of burnable absorber.
Three vertical channels of large diameter (158 mm) can be placed in the reflector of the reactor and used to obtain doped silicon.
The main reactor irradiation channels (eight vertical channels) are located in the core in neutron traps. Close to the optimal size of the trap allows the formation of its high thermal neutron flux density. Changing the composition of the medium in the channels (gas, water) or in the gaps between them and the FAs (displacers installing) allows you to change the hardness of the neutron spectrum, depending on the objectives of the experiment.
In 2007, in order to expand the experimental capabilities of the reactor it developed the irradiation unit (IU) for the radiation coloration of minerals. This IU is placed in the reflector of the reactor instead of the three channels of large diameter. You can still place two channels of large diameter for doped silicon.
In addition, at the reactor RBT-6 is the irradiation unit “Vessel", which is designed to test vessel steels of VVER and PWR in conditions simulating a wide range of operating conditions of neutron density and energy spectrum, on irradiation temperature, on the gradients of these parameters and the regimes of parameters changes during operation.
The results of the survey and assess the actual state suggest the possibility of further exploitation IND RBT-6 until 2020.

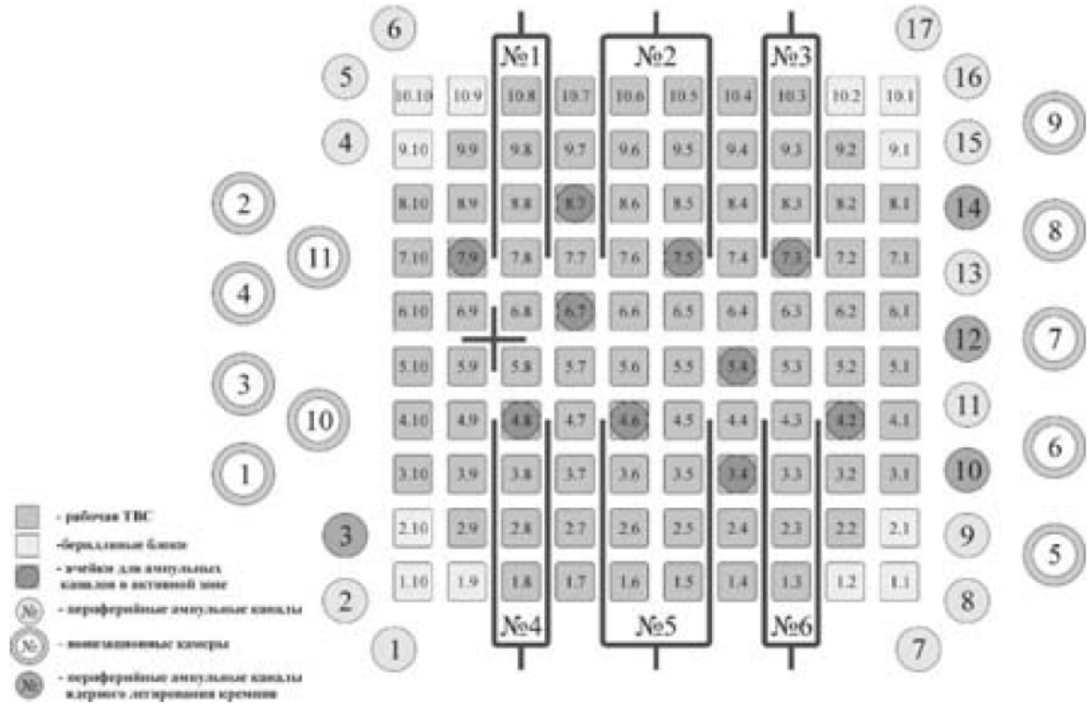
RIAR (Dimitrovgrad)

Pool-Type Reactor RBT-10/2
Year starting: 1983
Type: Pool
Therm Power Steady: 7 MW
Max thermal neutron flux: 1.6E13 (n/cm^2-s)
Max fast neutron flux: 9.6E13 (n/cm^2-s)
Uses spent fuel from the SM reactor

The pool-type reactors RBT-10 are designed for experiments on examination of changes in materials under irradiation, accumulation of radionuclides and silicon doping. The RBT-10/2 reactor uses spent fuel from the SM reactor, containing 18.4 to 50.7 kg of 50-85% enriched uranium fuel.

RIAR (Dimitrovgrad)

Pool-Type Reactor RBT-10/2



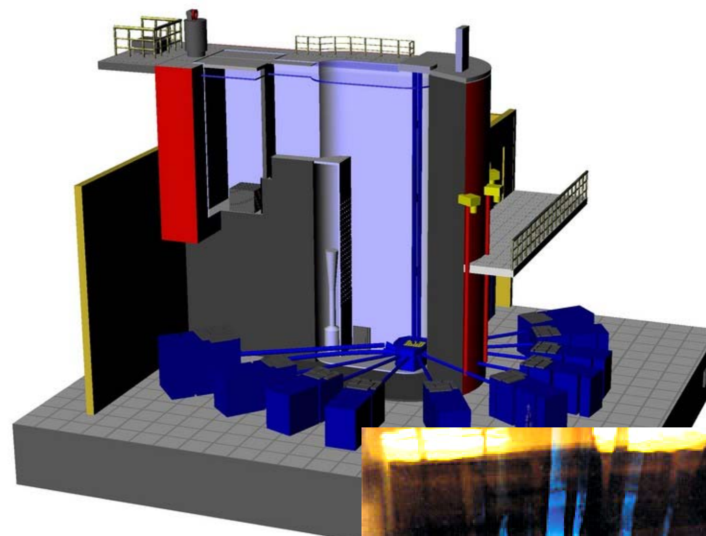
The reactor core RBT-10 / 2 is a right square prism from the base of 771 mm and 350 mm high. FAs in the amount of 78 units installed in the central support grid, which has 100 holes (10 × 10), located on a square lattice with spacing of 78 mm.

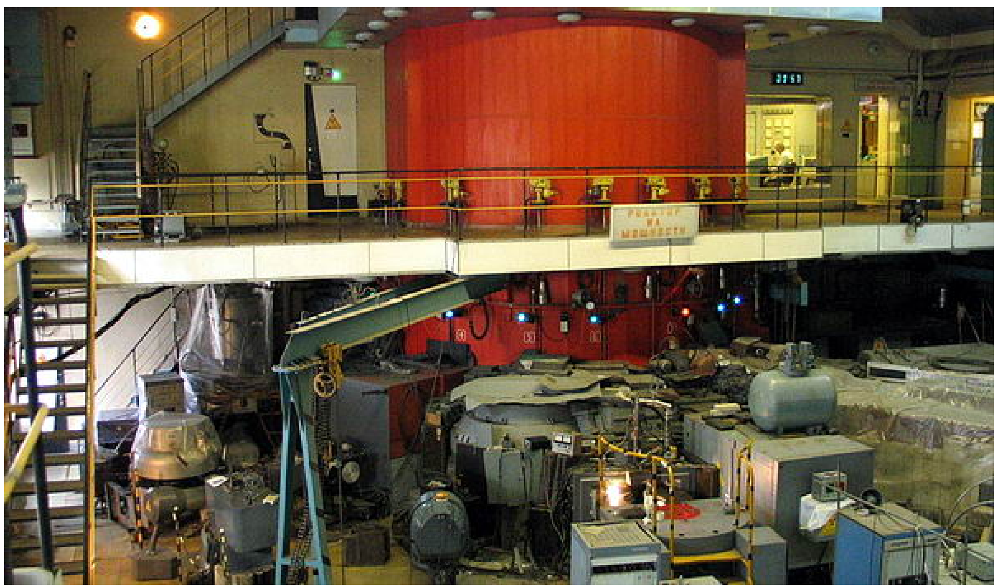
Ten cells of the core are designed for sealed channels, the location of which is shown in cartogram.

Active zone is collected mainly from spent SM fuel assemblies with burnup of 10 ÷ 30% but not more than 50%. Allowed loading of fresh FAs (based on the cartogram).

Kurchatov Institute (Moscow)

Pool-Type Reactor IR-8
Year starting: 1981
Type: Pool
Therm Power Steady: 8 MW
Max thermal neutron flux: 2.5E14 (n/cm^2-s)
Max fast neutron flux: 5.8E13 (n/cm^2-s)
90% enriched uranium fuel





The reactor is used for nuclear physics and solid state physics research, neutron-activation analysis, neutron radiography, radiation tests of materials, and isotope production.
There are 16 fuel assemblies (initial fuel enrichment 90%, the uranium content in each FA-0.294 kg of FM) in the core. The burnup averaged over the core volume is about 25%.

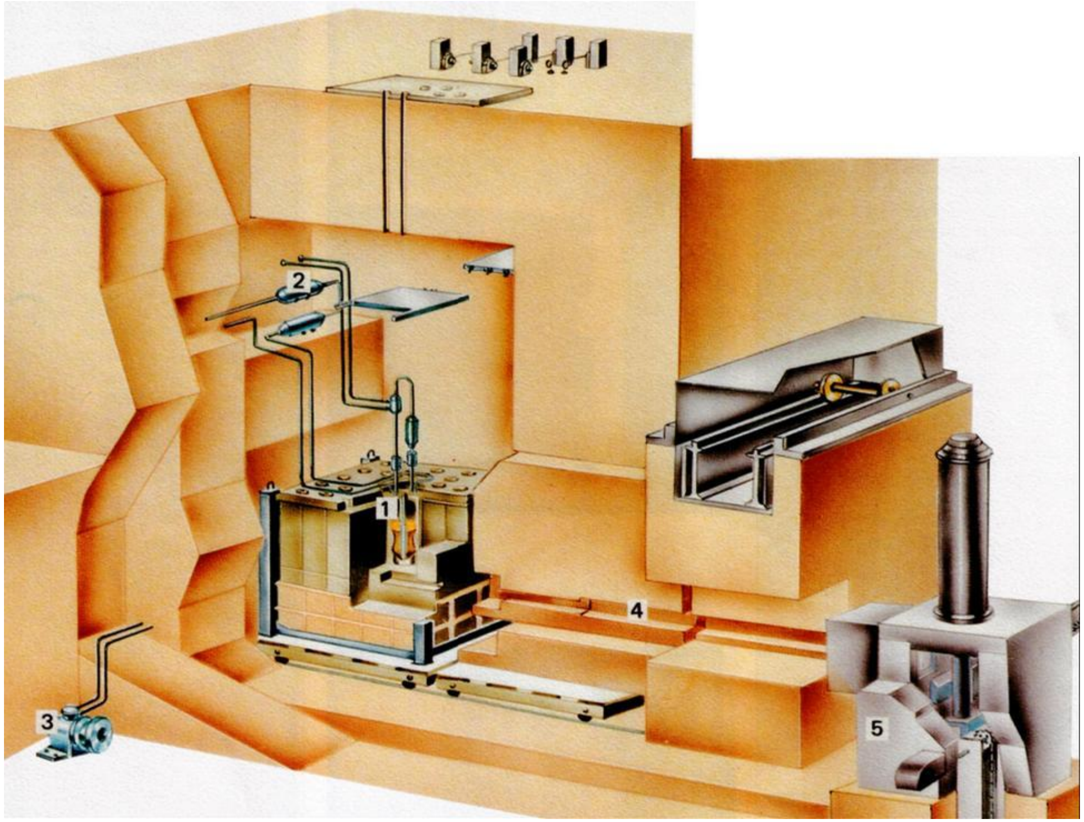
Kurchatov Institute (Moscow)

Tank-Type Reactor OR
Year starting: 1989
Type: Tank WWR
Therm Power Steady: 300 kW
Max thermal neutron flux: 3E12 (n/cm^2-s)
36% enriched uranium fuel

The OR research reactor is used to research and test neutron and gamma-radiation shields and to test the radiation stability of nuclear reactor equipment.
The OR reactor core loading is 3.8kg of 36% enriched uranium.

Kurchatov Institute (Moscow)

Reactor Argus
Year starting: 1989
Type: Homogeneous
Therm Power Steady: 20 kW
Max thermal neutron flux: 4E11 (n/cm^2-s)
Max fast neutron flux: 9.2E10 (n/cm^2-s)
90% enriched uranium fuel



The Argus reactor core volume is 22 liters of UO_2SO_4 solution containing 1.71kg of 90% enriched uranium.

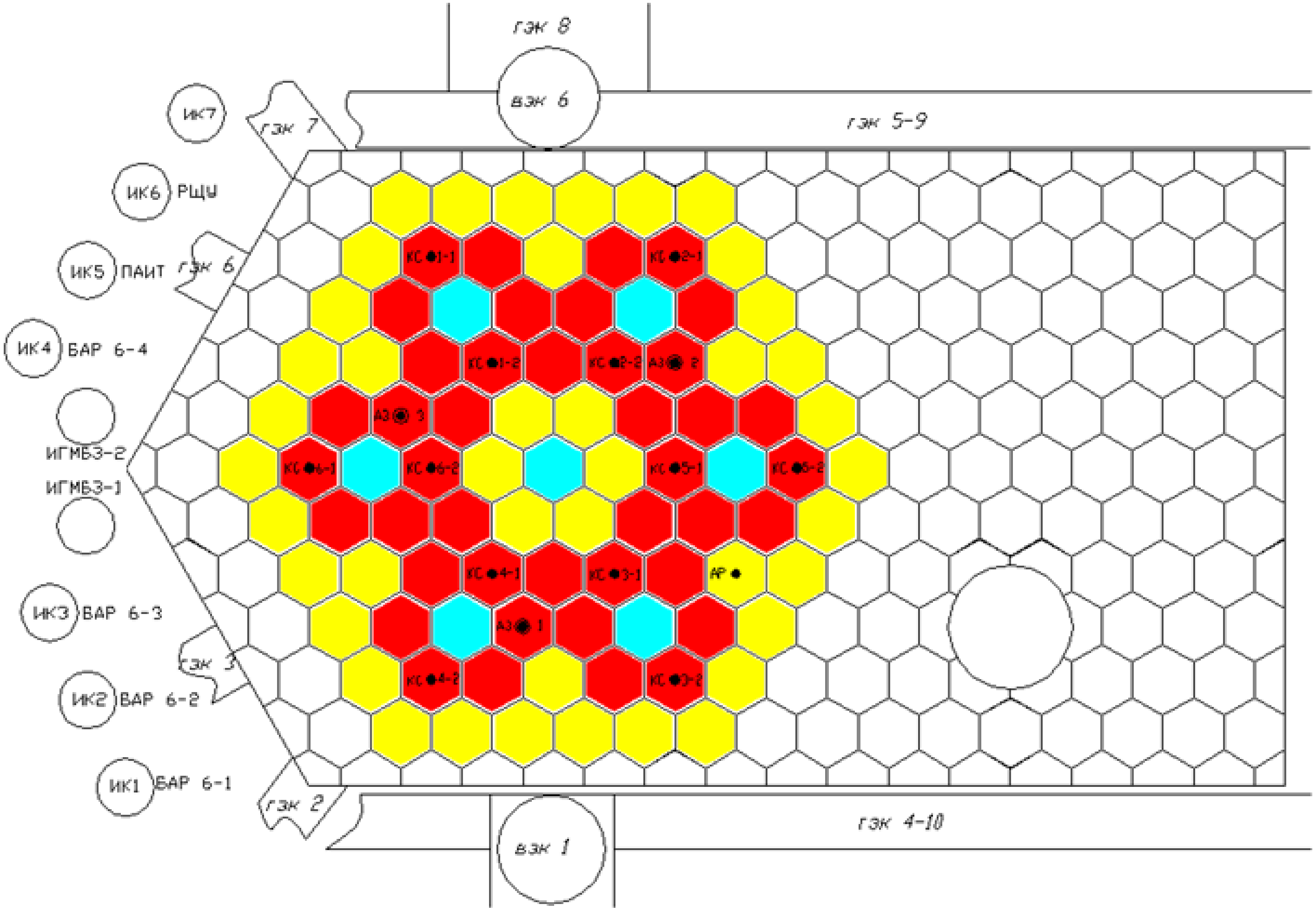
The reactor is used for neutron radiography, neutron activation analysis, and for the production of isotopes and nuclear filters.

Reactor Materials Institute (Zarechny)

Pool-Type Reactor IVV-2M
Year starting: 1966
Type: Pool
Therm Power Steady: 15 MW
Max thermal neutron flux: 5E14 (n/cm^2-s)
Max fast neutron flux: 2E14 (n/cm^2-s)
90% enriched uranium fuel

The core contains 42 fuel assemblies (initial fuel enrichment - 90%, uranium content in a FA is 0.25 kg).
In 1996-2006 carried out works on life extension IVV-2M. Allowed to operate until 2025.

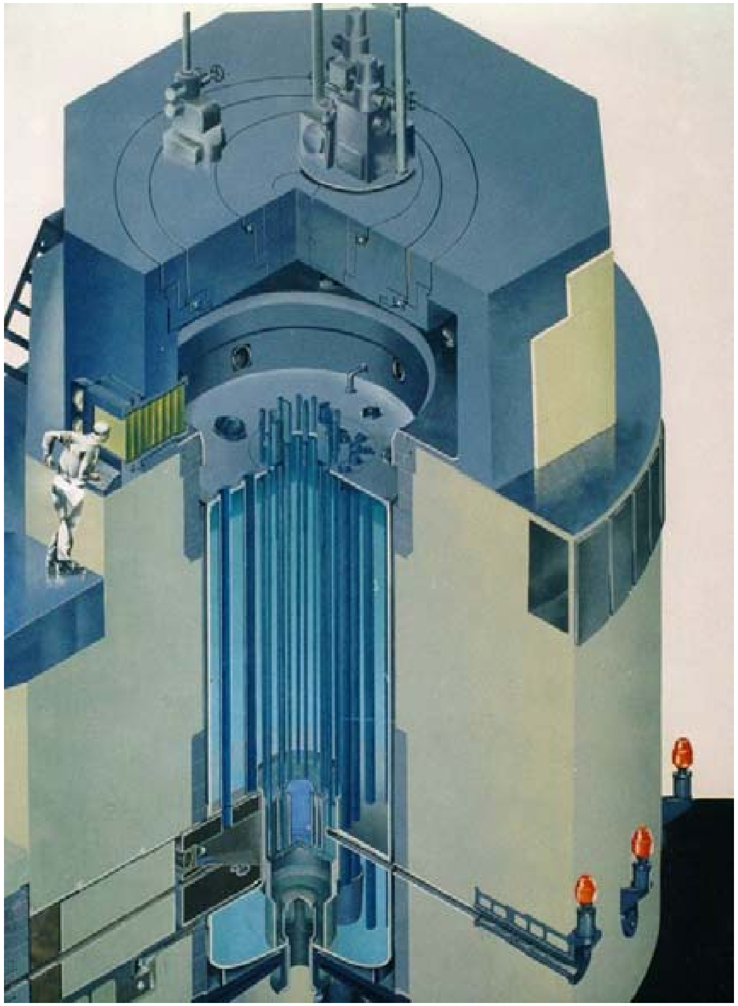
Pool-Type Reactor IVV-2M



Cartogram of IVV-2M core.

St.Petersburg Institute of Nuclear Physics

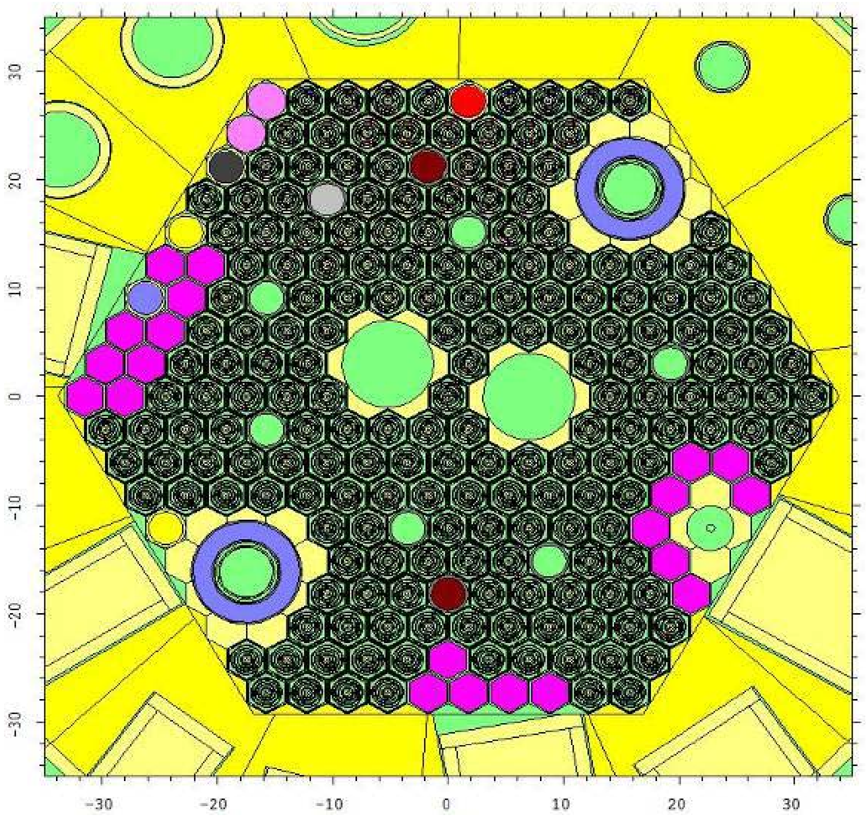
Pool-Type Reactor VVR-M
Year starting: 1959
Type: Pool
Therm Power Steady: 18 MW
Max thermal neutron flux: 4E14 (n/cm^2-s)
Max fast neutron flux: 1.5E14 (n/cm^2-s)
90% enriched uranium fuel



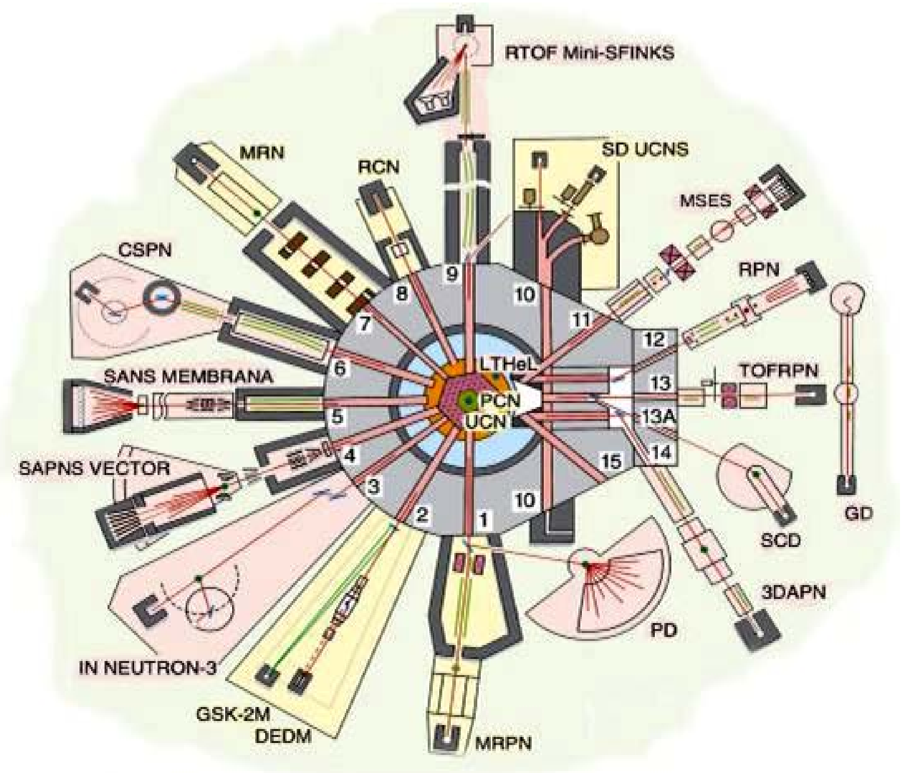
Allowed to operate until Jun 30, 2012.

St.Petersburg Institute of Nuclear Physics

Pool-Type Reactor VVR-M



Cartogram of VVR-M core. The core contains 145 FA (initial fuel enrichment - 90% uranium content per FA - 0.074 kg).



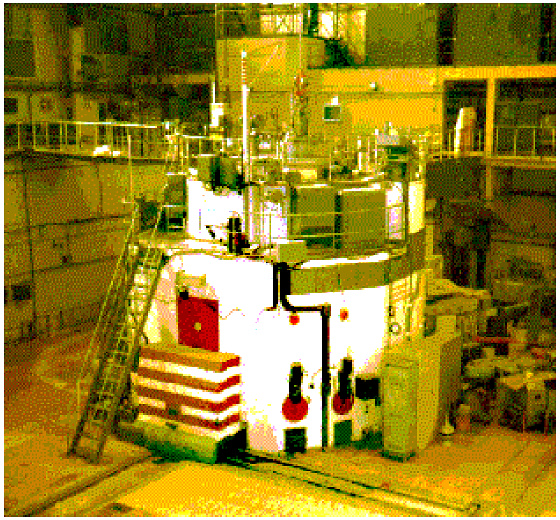
Layout of experimental facilities on the reactor VVR-M

Moscow Engineering and Physics Institute

Pool-Type Reactor IRT
Year starting: 1967
Type: Pool
Therm Power Steady: 2.5 MW
Max thermal neutron flux: 4.8E13 (n/cm^2-s)
Max fast neutron flux: 4.3E13 (n/cm^2-s)
90% enriched uranium fuel

Scientific Research Institute of Nuclear Physics (Tomsk)

Pool-Type Reactor IRT-T
Year starting: 1967
Type: Pool
Therm Power Steady: 6 MW
Max thermal neutron flux: 1.1E14 (n/cm^2-s)
Max fast neutron flux: 1.1E13 (n/cm^2-s)
90% enriched uranium fuel

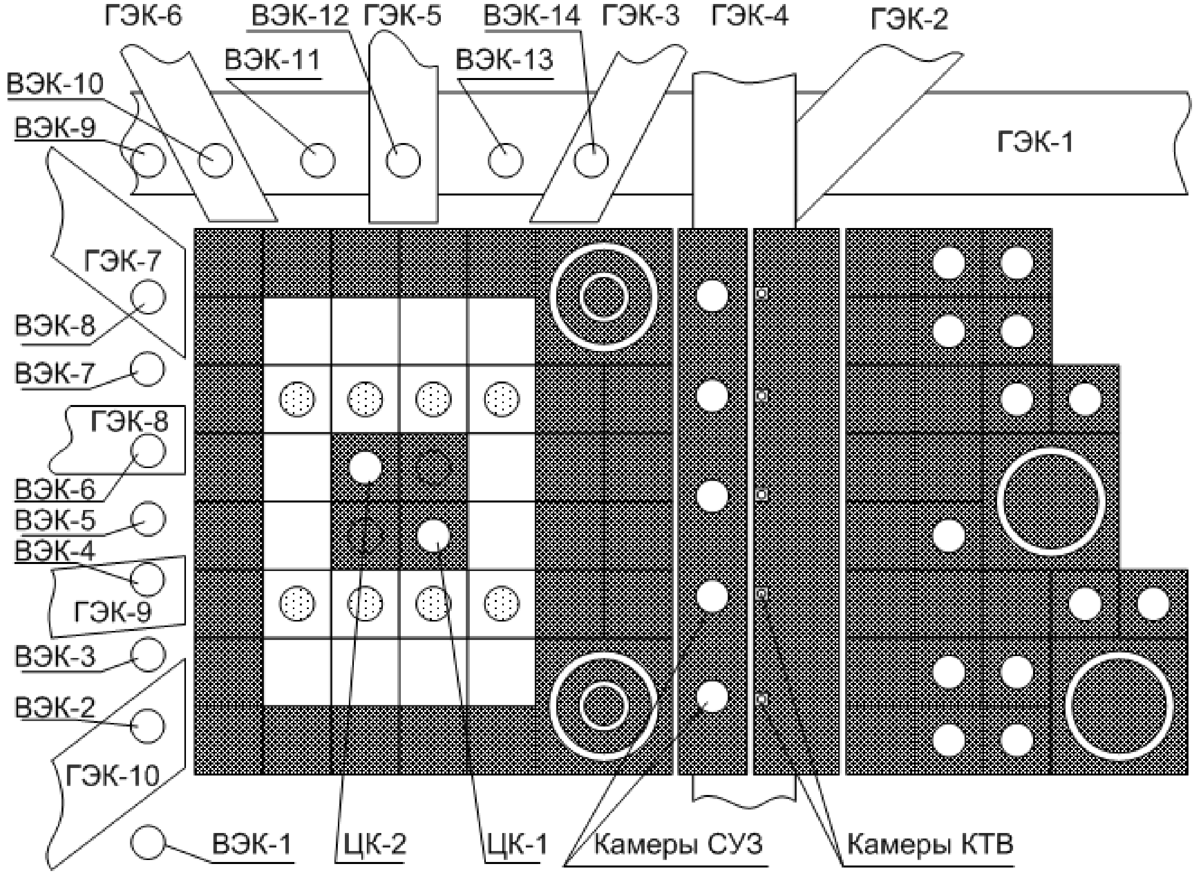


Since the start (1967) to 1970 the reactor IRT-T has worked with fuel rods type ЭК-10 with 10% enrichment in uranium-235. Reactor power was 2 MW. Since 1971, the reactor uses a new type of fuel assemblies of IRT-2M with 90% enriched uranium and beryllium reflector. After a series of further reconstruction the reactor has a thermal power of 6 MW (work is underway to increase power to 12 MW).

Further development work on the doping of silicon, the gathering of new radiopharmaceuticals, the implementation of works for a nuclear medical center in Tomsk, developing a complex of neutron-capture therapy requires an increase in power a nuclear reactor.

Allowed to operate until 2034.

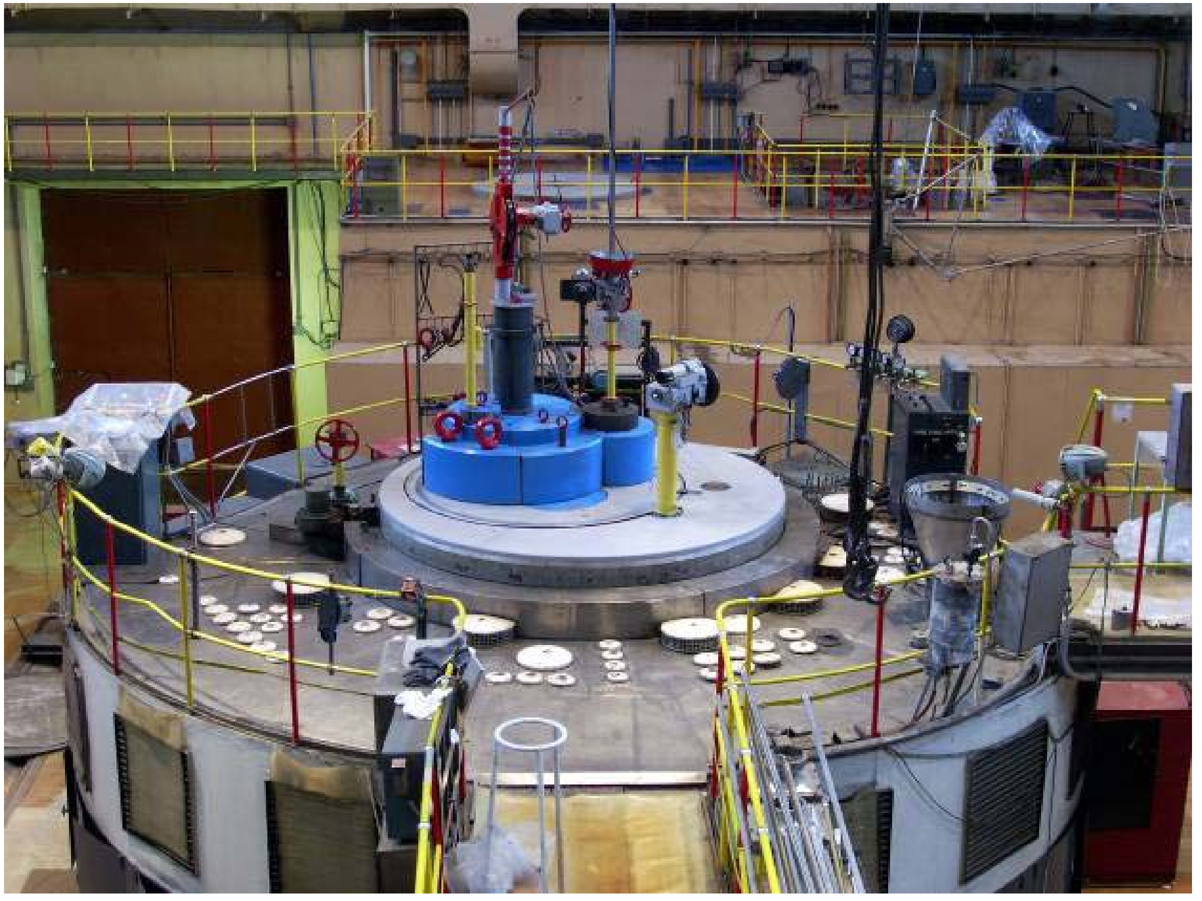
Pool-Type Reactor IRT-T



The reactor is equipped with 10 horizontal experimental channels, 8 of which have a diameter of 100 mm and 2 have a diameter of 150 mm, 14 vertical channels having a diameter of 52 mm and 4-channels of the central vertical diameter of 37 and 32 mm.

Karpov Institute of Physics and Chemistry (Obninsk)

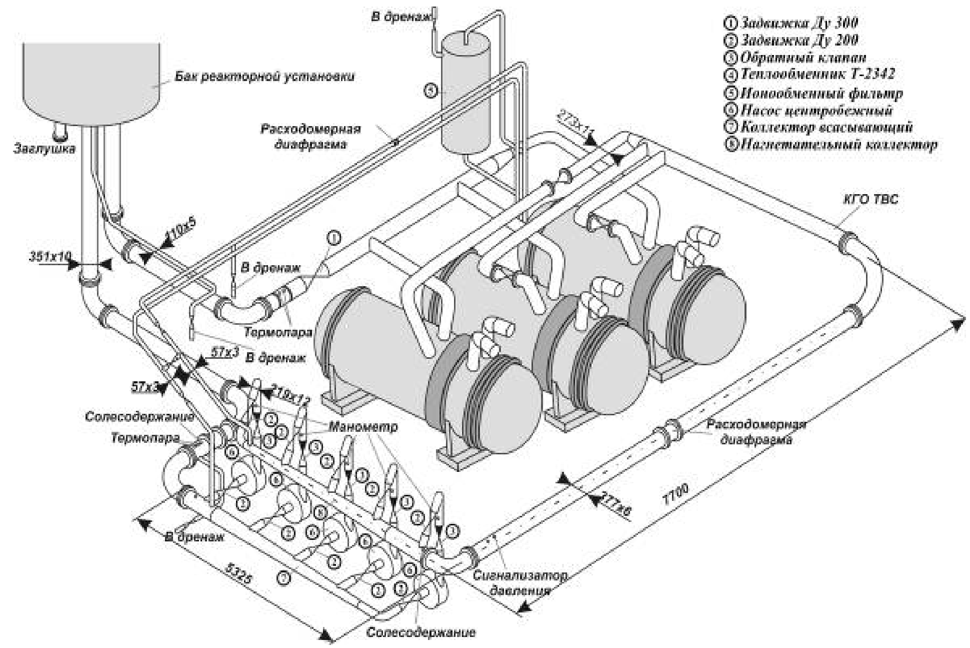
Tank-Type Reactor VVR-Ts
Year starting: 1964
Type: Tank WWR
Therm Power Steady: 15 MW
Max thermal neutron flux: 1.8E14 (n/cm^2-s)
Max fast neutron flux: 3.3E14 (n/cm^2-s)
36% enriched uranium fuel



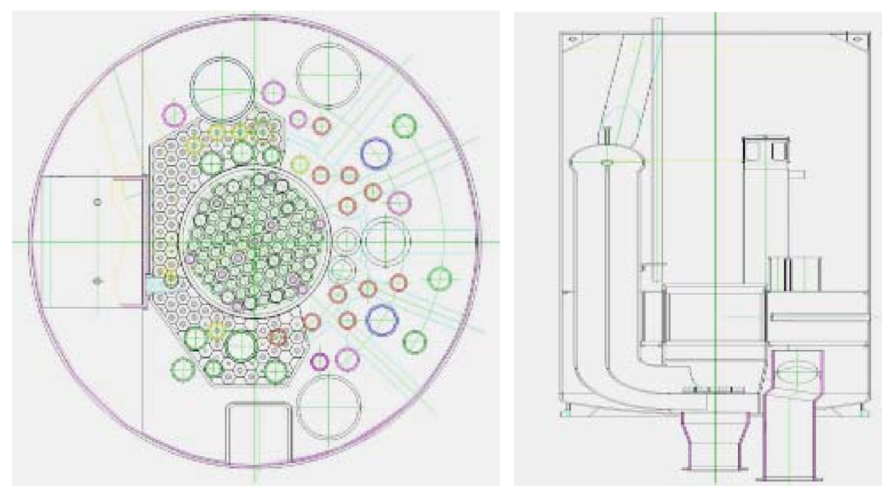
Karpov Institute of Physics and Chemistry (Obninsk)

Tank-Type Reactor VVR-Ts

The reactor VVR-Ts is specialized in a wide range of activities in the field of radiation chemistry, structural and materials research, activation analysis, neutron transmutation doping of semiconductors, etc.
The reactor is equipped with vertical and horizontal experimental channels of different diameters. Reactor Technology Complex includes 21 hot cells.
Given the success of research, as well as a favorable geographical position of the VVR-Ts, and in 1980 it was decided to reconstruct reactor.
The draft of the new reactor IVV-10 was developed. Complex of works on modernization and reconstruction of the reactor site has been done and continues to run. All work is carried out without interrupting the tecnological cycles of the VVR-Ts. The reactor produces radiopharmaceuticals and other products.



Contour VVR-Ts after reconstruction


Reactor IVV-10

Look at the possibility of conversion of Russian research reactors

RIAR (Dimitrovgrad)

MIR-M1:
Theoretically it is possible to convert the reactor to use fuel with a lower enrichment. Initial studies were performed.
Mini fuel elements enriched to 19.7%, containing silica matrix and a protective coating of uranium-molybdenum grains, tested under irradiation. The test results showed that such low-enriched fuel elements could provide the required parameters of a reactor.

SM-3:
A high-flux reactor with intermediate neutron (neutron flux in the trap is 5E15 n/cm^2-s). Very compact core (size 40x40x40 cm), beryllium reflector, a double vessel. Any changes in the core size and in the vessel internals are not possible.

RBT-6 and RBT-10/2:
In these reactors used as a fuel the irradiated nuclear fuel discharged from the reactor SM-3. This provides an efficient economy of reactors. Switch to another (fresh) fuel is possible but unreasonably because there is no object of theft.

Reducing the fuel enrichment in a reactor **SM-3**, **RBT-6**, **RBT-10/2** is impossible.

Kurchatov Institute (Moscow)

Statements of work, schedules prepared and contracts concluded for works on **IR-8**, **Argus** and **OR** reactors to determine ways to reduce fuel enrichment.

Currently the first phase of these contracts implemented.

However, the transfer of the results to customer hampered by the lack of an intergovernmental Agreement between the USA and the Russia for cooperation in the field of peaceful uses of nuclear energy.

Also, the implementing agreement concerning cooperation in research into feasibility of conversion of the Russian research reactors to use low enriched uranium fuel between the Rosatom and the U.S. Department of Energy while not formalized.

Reactor Materials Institute (Zarechny)

The analysis showed that the reactor can be converted into low-enriched fuel (19.7%) only when the specific density of uranium in the fuel kernel of 6.5 g/cm^3. It is virtually unattainable without a fundamental change in design and significant degradation of the reactor operation.

Given the extended period of operation (only 10 years) and duration of works to change the fuel, experts believe that the transfer to low-enriched fuel would be inappropriate.

St.Petersburg Institute of Nuclear Physics

Research work commissioned by U.S. organizations performed and published reports.

Studies have shown that switching to low-enriched fuel would require changing the design of fuel elements.

Since the financial and technological capabilities for the job is not defined, then experts believe that moving to low-enriched fuel would be inappropriate.

Moscow Engineering and Physics Institute

It is possible to convert the reactor to use fuel with a lower enrichment.

The University developed computational models that allow to determine with precision the parameters of reactors with different fuel enrichment.

Preliminary studies have shown that because of the specific operation mode of the reactor requirements for the new fuel can be less stringent. Therefore be expected to use fuel with low enrichment of one of several types (U9Mo-Al; UO2-Al).
The contract to further the work prepared.

Scientific Research Institute of Nuclear Physics (Tomsk)

The reactor and its infrastructure is significantly upgraded. The operation life extended to 2034. Decided to move the reactor on the power of 12 MW. At this point, switch to low-enriched fuel is possible.

Preliminary studies have shown the principal possibility of such a switching.

Karpov Institute of Physics and Chemistry (Obninsk)

It is possible to convert the reactor to use fuel with a lower enrichment.

Such a reactor is operating in Kazakhstan. To this reactor is estimated the possibility of the switching to the fuel of 19.7% enrichment. Experienced fuel assemblies shall be tested at present in the Reactor Materials Institute (Zarechny).

NPCC is ready to take up the creation of an eight-tube fuel assemblies.

Need to make calculations to confirm the neutronic and thermal hydraulic characteristics.

Conclusion

Thus, in principle, research reactors of the Rosatom, the Ministry of Education and Science, the Kurchatov Institute are ready to be converted into low-enriched fuel use.

The exception is the reactors of the Reactor Materials Institute and the St.Petersburg Institute of Nuclear Physics.