РОСАТОМ

НИКИЭТ им.Н.А.Доллежаля

JSC «NIKIET»

ASC "ROSATOM' COMPANY

The Research Reactors of New Generation with LEU Fuel

International Conference on Research Reactors: "Safe Management and Effective Utilization"

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NIKIET-designed Research Reactors

NIKIET is chief designer of about 30 research reactors in Russia and abroad.

Current Status of the Research Reactor Fleet

End of XX century	The beginning of XXI century
Vigorous advancement of research reactors (RR) all over the world changed into trend for a decrease in the number of operating research reactors.	• **Stabilization** of the number of operating RR**;** • Emerging interest in new facilities including countries that have no nuclear infrastructure.
HEU-fuel: The majority of RR normally operated on uranium enriched to more than 20%.	**LEU-fuel:** Work is in progress to reduce RR fuel enrichment in U-235 to less than 20%.
RR urgency: RR are still the cheapest and most readily available sources of high neutron fluxes.	

JSC "NIKIET"

- participates in the activities to develop and produce competitive Russian LEU-fuel;
- prepares technical proposals for design of future pool RR (100 kW to 30 MW in capacity).

The new RR are designed to support a broad spectrum of studies in:

- **Nuclear physics;**
- **Radiation material science;**
- **Neutron-activation analysis;**
- **Neutron radiography;**
- **Silicon doping;**
- **Production of medical and industrial isotopes; (^{99}Mo, ^{131}I, ^{125}I, ^{35}S, ^{32}P, ^{90}Y, ^{166}Ho, ^{60}Co, ^{153}Sm, ^{192}Ir);**
- **Expert and staff training;**
- **Neutron therapy**

Design Provisions and Principles for Pool RR

RELIABILITY

- application of design approaches and components well-proven during reactor operation in Russia and abroad;
- choice of coolant flow rates and pressure drops in the core to provide the required boiling margin and heat engineering index

SAFETY

- core arrangement deep in a pool of water;
- the reactor designed bars from core draining in the event of leaks in pipelines;
- leak monitoring, collection and return to the pool during accidents;
- no surface boiling at fuel elements and core components;
- adequate worth of CPS rods;
- passive safety systems;
- negative reactivity feedbacks;
- presence of beryllium in the reflector to ensure safe reactor control during startup;
- use of reference IRT-4M and VVR-M2 fuel assemblies (FA) with LEU fuel;
- development of new VVR-KN assemblies with LEU fuel;
- handling operations under water

EFFICIENCY

- high neutron flux in the reactor experimental devices;
- high burnup of discharged FA;
- high "reactor merit" (F/N);
- large variety of experimental positions

FLEXIBILITY

- reconfigurability of the reactor core;
- variability of the number and location of experimental channels

Russian LEU Fuel

FA for low- and average-powered RR developed:

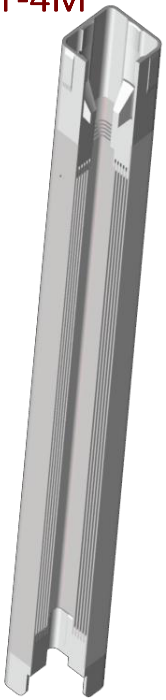
RR power	≤ 0.5 MW	10-15 MW	
FA type	VVR-M2	IRT-4M	VVR-KN

Technical characteristics of FA

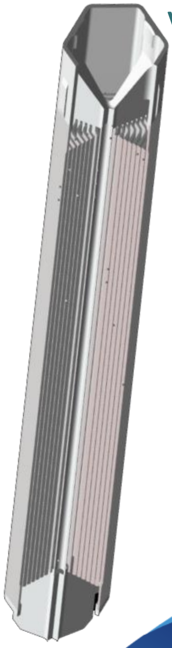
Commercially produced – VVR-M2, IRT-4M; prospective – VVR-KN

Parameter	VVR-M2	IRT-4M with 6/8 fuel elements	VVR-KN with 5/8 fuel elements
Fuel height, mm	600	600	600
Fuel material	UO_2-Al	UO_2-Al	UO_2-Al
Enrichment in U-235, %	19.7	19.7	19.7
U-235 content in FA, g	50	263.8/300	201.9/252.6
U concentration, g/cm^3	2.5	3	2.8
Fuel cladding	SAV-1	SAV-1	SAV-1
Structural material of end pieces	SAV-6	SAV-6 (AMg2)	SAV-6 (AMg2)
Reference reactors	DRR, BRR, WWR-M Kiev	IRT-1, IRT-Sofia, VR-1, LVR-15, WWR-CM Tashkent	Manufacture is to start in 2013

IRT-4M



VVR-KN



R&D Results Achieved in First Phase

Power range of advanced RR in demand in the market

- 1 MW reactor
- 10 MW reactor
- 20 MW reactor

Baseline designs of RR:
- **water-water;**
- **pool-type;**
- **with force coolant circulation;**
- **with LEU-fuel**

Basic characteristics of 1 MW, 10 MW and 20 MW RR:

Parameter	1 MW RR	10 MW RR		20 MW RR	
FA type	VVR-M2	IRT-4M	VVR-KN	IRT-4M	VVR-KN
Number of FA in the core	70	16	26	40	45
Core height, mm	600	600	600	600	600
Number of control rods	9	11	10	21	16
Control rod material	B_4C	B_4C	B_4C	B_4C	B_4C
Number of experimental holes: vertical (VEH) horizontal (HEH)	 4 4	 up to 25 4	 up to 24 4	 up to 20 4	 up to 17 4
"Reactor merit" in thermal neutrons,1/(cm^2s•W)	$4.4 \cdot 10^7$	$3.2 \cdot 10^7$	$3.3 \cdot 10^7$	$2.05 \cdot 10^7$	$2.3 \cdot 10^7$
Temperature effect, %Δk/k (at isothermal overheating for 73°)	-0.5	-0.3	-0.3	- 0.2	- 0.2
Average fuel burnup in discharged FA, %	50				
Coolant	Demineralized water				
Reflector	Beryllium				

Basic characteristics of 1 MW, 10 MW and 20 MW RR:

Neutron flux	1 MW RR	10 MW RR		20 MW RR	
	VVR-M2	IRT-4M	VVR-KN	IRT-4M	VVR-KN
Maximum thermal (E<0.625 eV) neutron flux, x10^{14} 1/cm^{2}s: in core in beryllium reflector	0.44 0.2	3.2 2	3.2 2	4.1 1.4	4.6 1.2
Undisturbed thermal (E<0.625 eV) neutron flux at pneumatic rabbit system locations, x10^{13}1/cm^{2}s:	0.02	0.2	0.2	0.4	1.2
Undisturbed neutron flux at the silicon doping channel (Ø 205 mm) location, x10^{13} 1/cm^{2}s: - thermal neutrons (E<0.625 eV) - fast neutrons (E<0.82 MeV)	- -	3.8 0.03	3.7 0.03	6 0.03	9 0.1
Neutron flux at horizontal hole outlets, x10^{10} 1/cm^{2}s: - thermal neutrons (E<0.625 eV) - Fast neutrons (E<0.82 MeV)	0.1-0.15 0.1-0.12	0.8-1.3 0.004-0.005	0.8-1.3 0.004-0.005	1.2-2 0.01-0.08	0.6-1.8 0.003-0.034

Current Progress with Designs of Advanced RR

Further development of RR designs as component of nuclear research center (NRC) is based

on the analysis of:
- modern and prospective trends in the RR application;
- foreign market demand

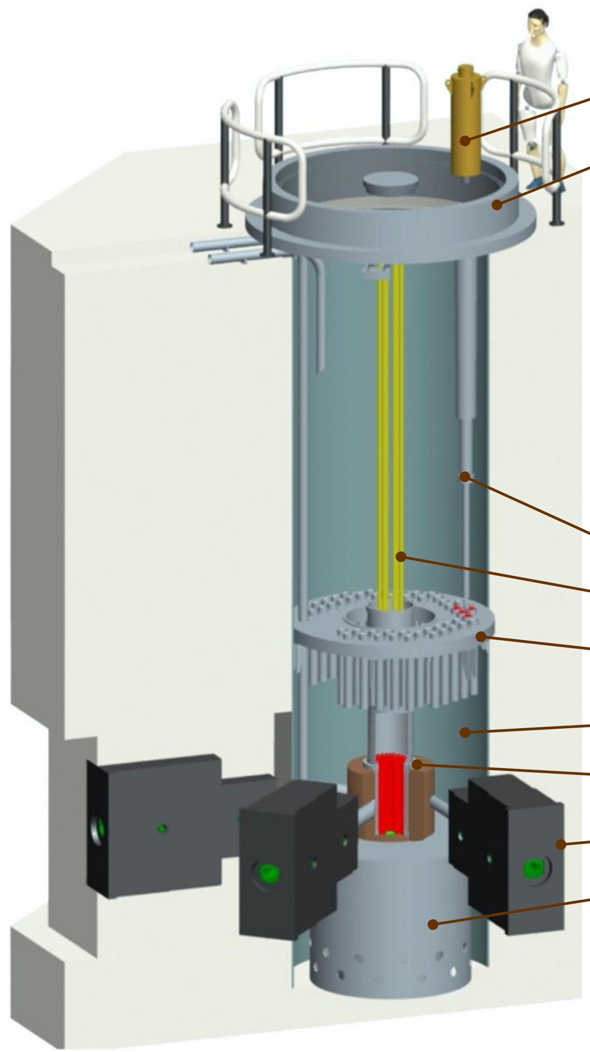
2 pool RR versions developed: - small reactor (of up to 0.5 MW) with natural coolant circulation;
- RR of average power (10-15 MW) with forced coolant circulation

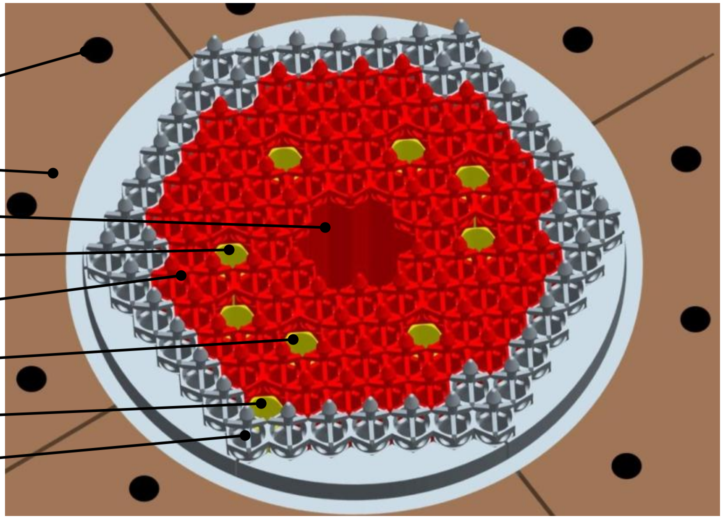
The following engineering and design concepts are developed as part of the technical proposals for the reactor facilities with low- and average-powered water-cooled pool RR:

- **circuitry designs,**
- **core and reflector layouts,**
- **estimates of neutronic and thermal-hydraulic parameters,**
- **core and reflector cooling systems,**
- **systems for handling of irradiated items,**
- **reactor facilities circuit diagrams.**

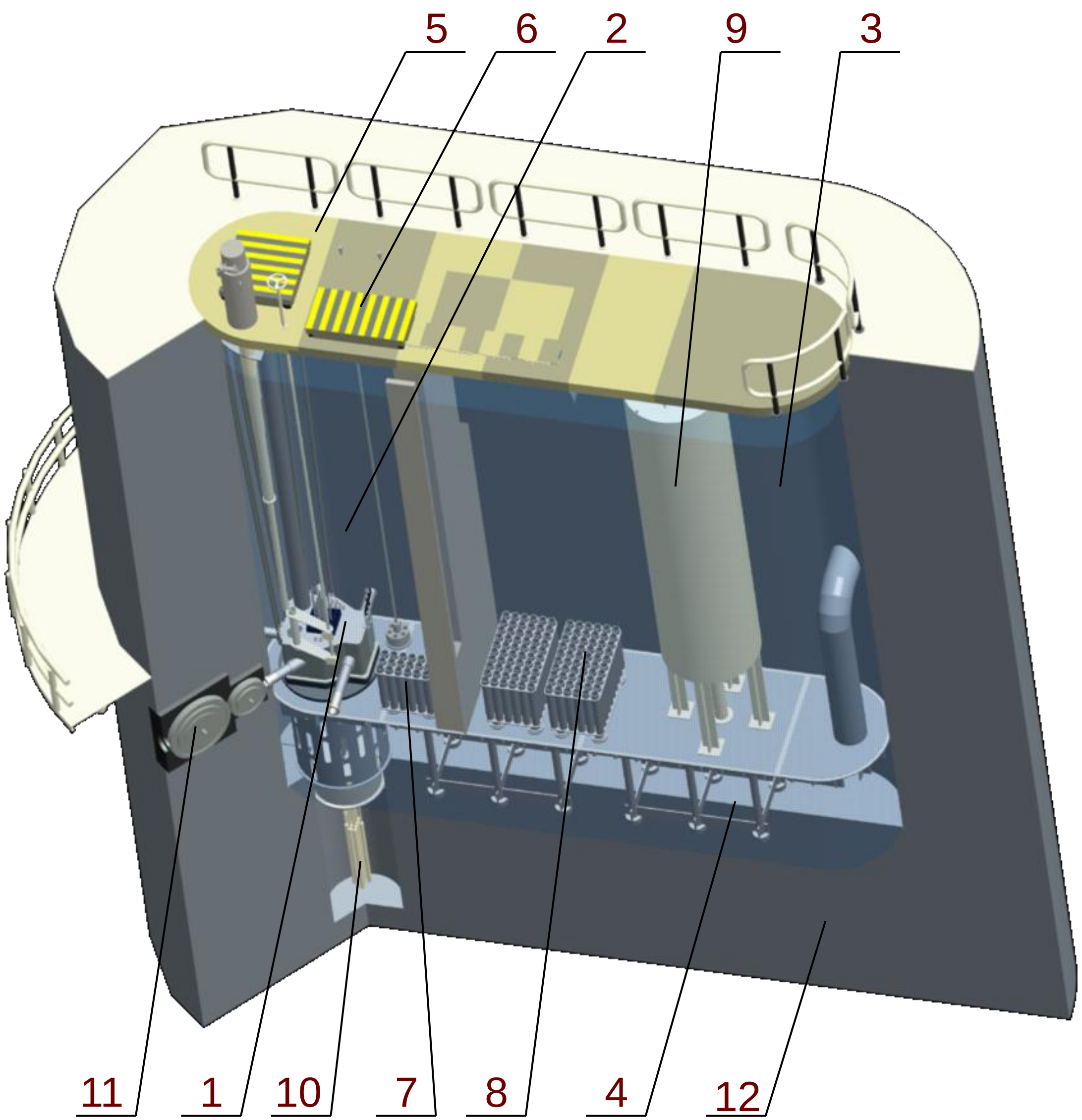
Also the cost of the design documentation development, equipment fabrication, reactor facilities construction and commissioning support activities will be determined.

Small RR (up to 0.5 MW)



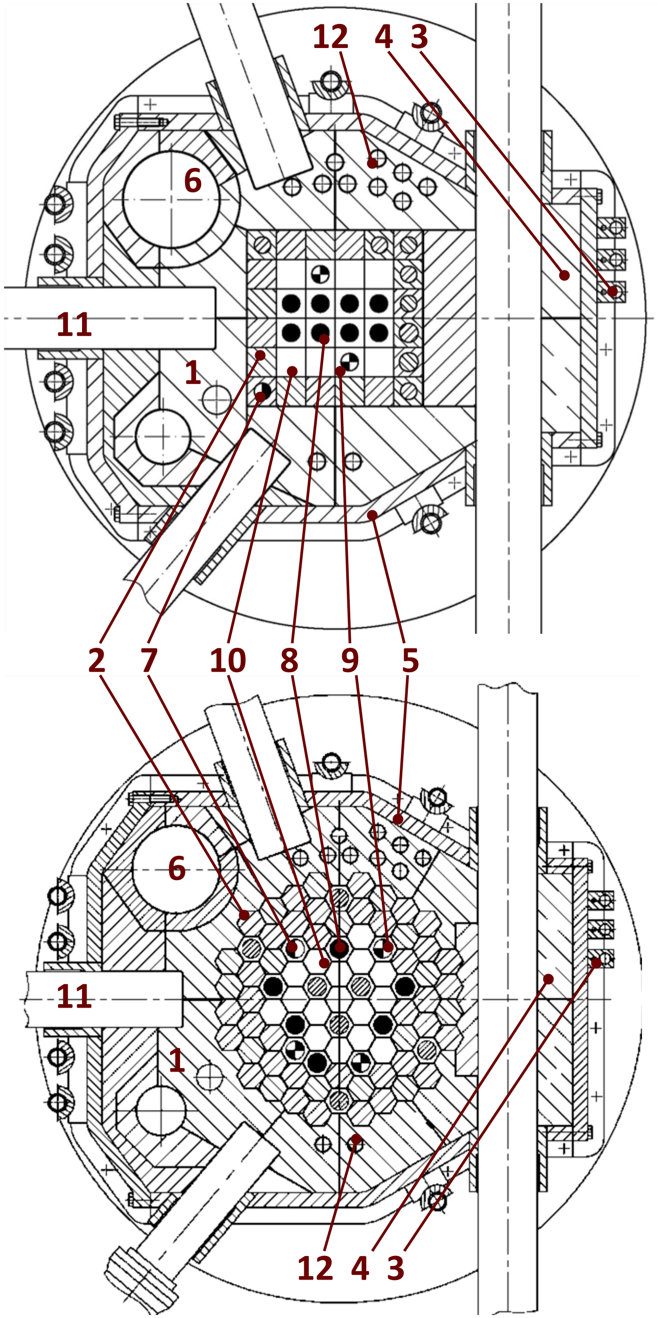


Average-powered RR (10-15 MW)



1 - core and reflector;
2 - reactor pool;
3 - storage pool;
4 - retainer tank;
5 - upper plate;
6 - sliding plate;
7 - intermediate storage;
8 - spent FA storage;
9 - emergency core cooling system (ECCS) tank;
10 - control and protection system (CPS) drives;
11 – HEH gate valve;
12 – biological shield body

Average-powered RR (10-15 MW)



Core layout with IRT-4M assemblies

Core layout with VVR-KN assemblies

1 – stationary reflector
2 – changeable reflector
3 – rabbit tube
4 – lead shield
5 – core case
6 – silicon doping channel
7 – automatic control rod
8 – shim rod
9 – scram rod
10 – FA
11 – HEH
12 – VEH

Experimental holes
can be inserted in:
-core cells,
-replaceable beryllium blocks,
- fixed reflector cells

and ensure:
-experimental capabilities,
- generation of commercial production

Basic Characteristics of Low- and Average-powered RR

Description of parameter	Parameter value	
FA	Tube type, LEU (UO_2 –Al, 19.7% U-235)	
Thermal power, MW	≤ 0.5 MW	10-15 MW
Core height, mm	600	600
Circulation	natural	forced, downward
Control rod material	B_4C	B_4C
Maximum thermal neutron flux, x10^{14} 1/cm^{2}s, not less than: in core in reflector	 0.2 0.1	 3.2 2
“Reactor merit”, x10^7 1/(cm^{2}s•W)	about 4	about 3.2
Number of experimental holes: - horizontal - vertical	 4 4	 ≤ 5 ≤ 24*
Average fuel burnup in discharged FA, %	50	
Coolant	Demineralized water	
Reflector	Beryllium	

* Structurally, the reactor design permits the number of VEH to be great enough. The list of the experimental devices for the reactor will be subject to update as the user desires.

Evolution Prospects of the NRC Projects

Evolution phases of the NRC baseline designs:

1. Selection of components for experimental facilities and laboratories the NRC includes.

2. Determination of the composition and the research-and-production, engineering and infrastructural support for:
   - *isotope production,*
   - *production of doped silicon,*
   - *materials research.*

3. Cost estimation for research-and-production, engineering and infrastructural support of the NRC in accordance with its designated function.

4. Development of the NRC design materials.

Conclusion

JSC "NIKIET" is ready to offer turnkey RR designs:

- **meet all international design standards for such facilities;**
- **give the potential customer a kind of a choice with respect to the NRC components depending on the RR application planned and the specific customer needs.**

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Thank you for your attention!