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1. Introduction

Over the whole time of NRF existence as a class of engineered devices, beginning with construction of the F-1 reactor, about 120 such facilities were built and operated in this country.

The Russian Federation has nuclear research facilities of practically all types and purposes, some of which are unique. Their geography is vast: from Gatchina and St. Petersburg to Tomsk. Their Operators are major scientific centers, research institutes, universities, research and production associations.

The 19 Russian Operators run 72 nuclear research facilities, which include 33 research reactors (29 in operation, 2 temporarily shut down (safe enclosure) and 2 under construction), 30 critical facilities (29 in operation, 1 temporarily shut down (safe enclosure)) and 9 subcritical facilities (6 in operation and 3 temporarily shut down (safe enclosure)). One research reactor is planned to be built with operation to begin in 2020 – this is multipurpose fast research reactor MBIR on the NIIAR site.

The location of NRFs, departmental affiliation of their Operators, their number, status and the main characteristics are presented in Figure 3 and in Tables 2–8.

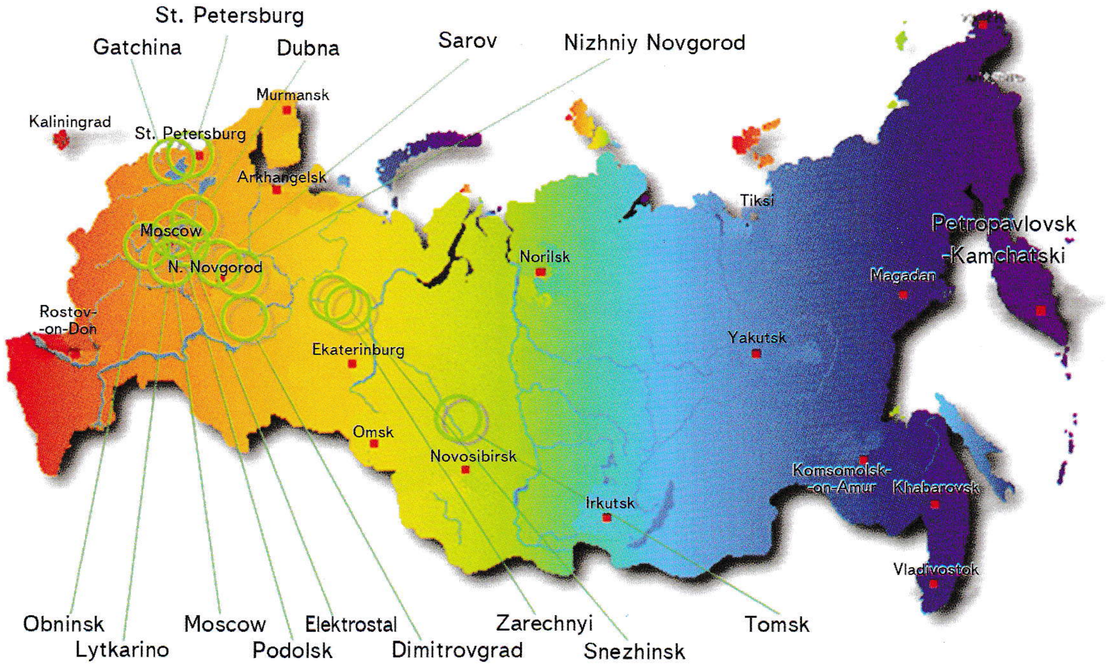

Fig.3. The geography of nuclear research facilities in Russia

Table 2

Russian Operators of nuclear research facilities

Location	Operator's name	
	full	abbreviated
St. Petersburg	FSUE "A.N. Krylov Shipbuilding Research Institute	KSRI
Gatchina, Leningrad Region	FBFI "B.P. Konstantinov Petersburg Nuclear Physics Institute"	PNPI
Obninsk, Kaluga Region	FSUE "A.I. Leipunsky SSC Institute of Physics and Power Engineering" (IPPE)	IPPE
	FSUE "L.Ya. Karpov Research Institute of Physics and Chemistry"	NIFHI
Moscow	FBFI National Research Center "Kurchatov Institute"	NRC KI
	National Research Nuclear University "Moscow Engineering and Physics Institute" (MEPhI)	MEPhI
	OJSC "N.A. Dollezhal Research and Development Institute of Power Engineering"	NIKIET
	FBFI SSC "Institute of Theoretical and Experimental Physics"	ITEP
	National Research University "Moscow Power Engineering Institute"	MPEI
Dubna, Moscow Region	Joint Institute for Nuclear Research	JINR
Lytkarino, Moscow Region	FSUE "Research Institute for Instrumentation"	NIIP
Podolsk, Moscow Region	OJSC "Experimental Design Bureau" "GIDROPRESS"	OKB GIDROPRESS
Elektrostal, Moscow Region	OJSC "Machine Building Factory"	MSZ (ELEMASH)
Nizhniy Novgorod	OJSC "I.I. Afrikantov Experimental Machine Design Bureau"	OKBM Afrikantov
Sarov, N. Novgorod region	FSUE "Russian Federal Nuclear Center – All-Russian Research Institute of Experimental Physics"	VNIIEF
Dimitrovgrad, Ulyanovsk Region	OJSC "SSC Research Institute of Nuclear Reactors"	RIAR
Zarechnyi, Sverdlovsk Region	OJSC "Institute of Reactor Materials"	IRM
Snezhinsk, Chelyabinsk Region	FSUE "Russian Federal Nuclear Center – All-Russian Ye.I. Zababakhin Research Institute of Engineering Physics"	VNIITF
Tomsk	FBFI "Tomsk National Research Polytechnical University. Institute of Physics and Engineering"	FTI TPU

Table 3

Russian Operators of nuclear research facilities and their departmental affiliation

Departmental affiliation	Operator	Location	Number of facilities			
			Total	RR*	CF*	SCF*
State Corporation "Rosatom"	RIAR	Dimitrograd	8	6	2	0
	IPPE	Obninsk	6	1	5	0
	IRM	Zarechnyi	1	1	0	0
	NIKIET	Moscow	2	1	0	1
	NIIP	Lytkarino	2	2	0	0
	MSZ	Elektrostal	2	0	2	0
	OKBM Afrikantov	Nizhniy Novgorod	2	0	2	0
	OKB GIDROPRESS	Podolsk	2	0	0	2
	NIFHI	Obninsk	1	1	0	0
	VNIIF	Sarov	7	5	2	0
	VNIITF	Snezhinsk	5	4	1	0
RF Ministry of Education and Science	JINR	Dubna	1	1	0	0
	MEPhI	Moscow	6	1	0	5
	FTI TPU	Tomsk	1	1	0	0
	MPEI	Moscow	1	0	0	1
RF Government	NRC KI	Moscow	20	6	14	0
	PNPI	Gatchina	3	2	1	0
	ITEP	Moscow	1	0	1	0
RF Ministry of Industry	KSRI	St. Petersburg	1	1	0	0
Total			72	33	30	9

** RR – research reactor; CF – critical facility; SCF – subcritical facility*

Table 4

Distribution of Russian nuclear research facilities by types and status

NRF type	Number of facilities				
	Total	Operating	Safe enclosure	Under construction	Planned
RR	34	29	2	2	1
CF	30	29	1	0	0
SCF	9	6	3	0	0
Total	73	64	6	2	1

Table 5

Russian Operators and distribution of their nuclear research facilities by status and types

Operator	Number of NRFs												
	Total	Operating			Safe enclosure			Under construction			Planned		
		RR	CF	SCF	RR	CF	SCF	RR	CF	SCF	RR	CF	SCF
RIAR	9	6	2								1		
IPPE	6	1	5										
IRM	1	1											
NIKIET	2				1		1						
NIIP	2	1						1					
MSZ	2		2										
OKBM Afrikantov	2		2										
OKB GIDROPRESS	2						2						
NIFHI	1	1											
VNIIF	7	5	2										
VNIITF	5	4	1										
JINR	1	1											
MEPhI	6	1		5									
FTI TPU	1	1											
MPEI	1			1									
NRC KI	20	6	13			1							
PNPI	3	1	1					1					
ITEP	1		1										
KSRI	1				1								
Total in Russia	73	29	29	6	2	1	3	2	0	0	1	0	0

Table 6

Russian research reactors (as of 31.12.2011)

No.	Name	Operator	Location	First criticality, year	Status
1.	SM-3	RIAR	Dimitrovgrad	1961	Operating
2.	RBT-6	RIAR	Dimitrovgrad	1975	
3.	MIR.M1	RIAR	Dimitrovgrad	1966	
4.	RBT-10/2	RIAR	Dimitrovgrad	1983	
5.	BOR-60	RIAR	Dimitrovgrad	1969	
6.	VK-50	RIAR	Dimitrovgrad	1964	
7.	BARS-6	IPPE	Obninsk	1994	
8.	IVV-2M	IRM	Zarechnyi	1966	
9.	BARS-4	NIIP	Lytkarino	1980	
10.	VVR-c	NIFHI	Obninsk	1964	
11.	GIR-2	VNIIEF	Sarov	1992	
12.	BIGR	VNIIEF	Sarov	1976	
13.	BR-1M	VNIIEF	Sarov	2007	
14.	BR-K1	VNIIEF	Sarov	1986	
15.	VIR-2M	VNIIEF	Sarov	1979	
16.	BARS-5	VNIITF	Snezhinsk	1986	
17.	IGRIK	VNIITF	Snezhinsk	1975	
18.	EBR-L	VNIITF	Snezhinsk	1981	
19.	YaGUAR	VNIITF	Snezhinsk	1988	
20.	IBR-2M	JINR	Dubna	2011	
21.	IRT MIFI	MEPhI	Moscow	1967	
22.	IRT-T	FTI TPU	Tomsk	1967	
23.	Gamma	NRC KI	Moscow	1981	
24.	Argus	NRC KI	Moscow	1981	
25.	Gidra	NRC KI	Moscow	1971	
26.	F-1	NRC KI	Moscow	1946	
27.	OR	NRC KI	Moscow	1988	
28.	IR-8	NRC KI	Moscow	1981	
29.	VVR-M	PNPI	Gatchina	1959	
30.	IR-50	NIKIET	Moscow	1961	Safe enclosure
31.	U-3	KSRI	St. Petersburg	1964	
32.	IRV-M2	NIIP	Lytkarino	1974	Under construction
33.	PIK	PNPI	Gatchina	2011	

Table 7

Russian critical facilities (as of 31.12.2011)

No.	Name	Operator	Location	First criticality, year	Status
1.	SM	RIAR	Dimitrovgrad	1970	Operating
2.	MIR	RIAR	Dimitrovgrad	1966	
3.	AMBF-2-1600	IPPE	Obninsk	1984	
4.	BFS-1	IPPE	Obninsk	1962	
5.	BFS-2	IPPE	Obninsk	1969	
6.	MATR-2	IPPE	Obninsk	1963	
7.	FS-1M	IPPE	Obninsk	1970	
8.	Facility No. 4	MSZ	Elektrostal	1967	
9.	Facility No. 5	MSZ	Elektrostal	1967	
10.	ST-659	OKBM Afrikantov	Nizhniy Novgorod	1963	
11.	CT-1125	OKBM Afrikantov	Nizhniy Novgorod	1975	
12.	IKAR-S	VNIIEF	Sarov	2004	
13.	FKBN-2M	VNIIEF	Sarov	2001	
14.	FKBN-2	VNIITF	Snezhinsk	2000	
15.	P	NRC KI	Moscow	1987	
16.	SK-fiz	NRC KI	Moscow	1997	
17.	SF-1	NRC KI	Moscow	1972	
18.	SF-7	NRC KI	Moscow	1975	
19.	Kvant	NRC KI	Moscow	1990	
20.	Delta	NRC KI	Moscow	1985	
21.	Narciss-M2	NRC KI	Moscow	1983	
22.	Astra	NRC KI	Moscow	1981	
23.	Grog	NRC KI	Moscow	1980	
24.	RBMK	NRC KI	Moscow	1981	
25.	V-1000	NRC KI	Moscow	1986	
26.	Efir-2M	NRC KI	Moscow	1973	
27.	Aksamit	NRC KI	Moscow	2002	
28.	PIK PM	PNPI	Gatchina	1983	
29.	MAKET	ITEP	Moscow	1976	
30.	UG	NRC KI	Moscow	1965	Safe enclosure

Table 8

Russian subcritical facilities (as of 31.12.2011)

No.	Name	Operator	Location	First criticality year	Status
1.	VVER	MEPhI	Moscow	1974	Operating
2.	UV-1	MEPhI	Moscow	1983	
3.	UV-2	MEPhI	Moscow	1972	
4.	UVPSh	MEPhI	Moscow	1964	
5.	UG	MEPhI	Moscow	1955	
6.	UV	MPEI	Moscow	1980	
7.	FS-2	NIKIET	Moscow	1972	Safe enclosure
8.	7KVD	OKB GIDROPRESS	Podolsk	1979	
9.	7KND	OKB GIDROPRESS	Podolsk	1978	

The information collected in this book gives an impressive picture of Russian nuclear research facilities in their current status which offer wide possibilities to domestic and foreign experimenters for their various studies.

The leading role among these facilities belongs obviously to research reactors whose experimental capabilities are by far greater than those of critical and subcritical rigs. It appears logical therefore to point out the specific features of Russian research reactors that set them off from all other nuclear facilities, on the one hand, and make them unique, on the other. These features relate to the design of Russian reactors, their fuel and experimental applications.

The design of the first Russian research reactor, F-1, was relatively simple but suitable for serving its main purpose – experimental demonstration of the feasibility of a controlled chain fission reaction. The need for higher power and neutron fluxes in experiments and use of these reactors for increasingly complicated and far-reaching tasks called for more sophisticated design approaches, for different special coolants, including heavy water and sodium.

The first research reactor equipped with a cooling system was the heavy-water TVR designed in the late 1940s and built on the site of the Moscow Institute of Theoretical and Experimental Physics.

In 1952, the LIPAN Laboratory (the NRC "Kurchatov Institute" today) brought into action the RFT – a loop-type test reactor, which gave rise to extensive studies on the behavior of reactor materials and provided essential data for the design of nuclear reactors in the 1950s and 1960s.

In those years, research reactors were at the zenith of their evolution. The striking diversity of design features brought into effect in the 1950s–1960s demonstrated the vast creative potential of the national school of engineering. Even the reactors built to standard designs had individuality.

No lesser design variety was shown by domestic critical assemblies which are referred to as "zero power reactors" in the world.

The widest application in Russia and abroad was found by pool-type reactors, IRT and VVR first of all. The power of these reactors varies typically from 5 to 10 MW, with the fast and thermal neutron flux found between 10^{13} and 10^{14} $cm^{-2}\cdot s^{-1}$, as dictated by the experimental needs of those days.

Extensive development of in-pile material testing activities generated a need for such research facilities where materials for reactors of different designs could be tested simultaneously. To this end, pressure-tube tank-in-pool reactors, such as MR and MIR, were designed, which were perfectly convenient for loop tests.

Neutron flux in experiments – the main indicator of RR efficiency – was growing very quickly and reached 10^{14} $cm^{-2}\cdot s^{-1}$ as early as the beginning of the 1950s. In 1961, the 50 MW SM reactor was put into operation with the record-setting neutron flux level of $2.5\cdot 10^{15}$ $cm^{-2}\cdot s^{-1}$. Later on, the reactor power and the thermal neutron flux were raised respectively to 100 MW and to $5\cdot 10^{15}$ $cm^{-2}\cdot s^{-1}$, which has not been surpassed to this day for water-cooled water-moderated research reactors of stationary power.

The engineering approaches designed into pool-type research reactors made possible their later upgrading with considerable increase of power and extension of experimental capabilities. One example is the VVR-M reactor at PNPI, whose operating power is 18 MW.

Aperiodic pulsed reactors proved their efficiency in certain neutronic studies as well as in tests of materials and components in pulsed modes.

The unique pulsed reactors of periodic action – IBR-30 and IBR-2 – combined the capabilities of stationary neutron flux reactors with those of aperiodic pulsed reactors.

Quite a few research reactors built to Soviet and Russian designs have successfully operated in this country and abroad. Their experimental capabilities and power are growing, as allowed by upgrades and retrofitting, which suggests that the scientific and technical potential of these reactors is by no means exhausted.

Russian research reactors owe their high efficiency largely to the original design of fuel elements and fuel assemblies.

The domestic extrusion process in use for manufacture of tubular fuel elements, which has been developing for many years and has made substantial progress, allows producing fuel of various shapes, adapted to different reactors and experimental devices. Given tubular fuel elements, it is possible to produce fuel assemblies that have no structural materials other than the fuel cladding, which has maximized the heat transfer area per unit volume of the core. This, in turn, has increased considerably the power per unit volume of the core and, consequently, the neutron flux in experimental devices.

The design specifics of domestic fuel elements and assemblies enabled Russian researchers to take active part in the uranium enrichment reduction program for research reactors. After conversion of highly enriched uranium (HEU) to low enriched uranium (LEU), the fuel elements and assemblies produced within the framework of the above program made it possible to keep the reactor parameters at the level achieved with the use of HEU.

Research reactor applications cover all areas where high neutron fluxes are required.

Fundamental research with the use of neutron beams has produced unique results associated with inelastic neutron scattering.

A large number of loop channels with various parameters was provided for the MR and MIR test reactors, where they were used for testing all types of fuel for NPP reactors and other nuclear facilities under various conditions, including transients and accidents.

Tests of fuel and structural materials carried out in fast spectrum research reactors yielded results that paved the way for successful development and operation of fast power reactors.

Research reactors are a very convenient and efficient tool for production of radioisotopes. They cover practically the whole spectrum of reactor radionuclides, including transuranics, as well as isotopes of superhigh specific activity, which can only be generated under conditions of high neutron fluxes.

The PIK reactor at PNPI is expected to be commissioned in the near future. This 100 MW reactor is designed for fundamental research with the use of neutron beams. The ideas translated into the PIK design back at the early stage of its development, have not lost their importance to this day and lie at the root of many RR designs.

Table 9

Russian nuclear research facilities under decommissioning

No.	Type	Name	Operator	Location	First criticality year	Shutdown year	Decom beginning
1.	RR	RBT-10/1	RIAR	Dimitrovgrad	1982	2004	2005
2.	RR	ARBUS-AST1	RIAR	Dimitrovgrad	1963	1988	1990
3.	RR	BR-10	IPPE	Obninsk	1958	2002	2002
4.	RR	AM	IPPE	Obnisk	1954	2002	2002
5.	RR	27/VM	IPPE	Obninsk	1956	1986	1986
6.	RR	27/VT	IPPE	Obninsk	1958	1978	1978
7.	RR	TVR	ITEP	Moscow	1949	1986	1987
8.	RR	MR	NRC KI	Moscow	1963	1992	2003
9.	CF	RF-GS	IPPE	Obninsk	1962	2003	2003
10.	CF	MER	KSRI	St. Petersburg	1964	1969	2004
11.	CF	G-1	KSRI	St. Petersburg	1989	1998	2004
12.	SCF	SO-2M	VNIIHT	Moscow	1975	2001	2004
13.	SCF	Stend	SPIMash	St. Petersburg	1975	2002	2010
14.	SCF	R-1	KSRI	St. Petersburg	1991	1999	2004

Coming at the next stage of development is a multipurpose fast reactor of a new generation which has received the name of MBIR. Its unique experimental capabilities will make it fit not only for studies of fast reactor materials but also for conducting a whole spectrum of investigations requiring high fast neutron fluxes.

This book is devoted to the operating nuclear research facilities in Russia; nevertheless, it appears worthwhile to complete the picture by adding some information about the facilities that reached the stage of decommissioning. The total number of facilities decommissioned to date is about 40, including research reactors, critical and subcritical facilities. Today, 14 facilities are in the process of decommissioning, and their data may be found in Table 9.

The main reasons for decommissioning are generally completion of the research program, the end of the design service life, impossibility of continuing operation because of technical complexity or economic inexpedience of meeting the increased reliability and safety requirements.

Each of these facilities has made its own contribution to development of nuclear science, engineering and industry, to vocational education, training and special exercises.

Decommissioning of nuclear research facilities has provided substantial experience of handling various irradiated materials and bringing nuclear facilities to a state of radiation safety. This experience may prove useful in decommissioning of research reactors not only in Russia but also abroad.

The book sections that follow will provide information about the nuclear research facilities that are in operation today, temporarily shut down (safe enclosure), under construction and planned to be built.