



## BN-600 AND BN-800 OPERATING EXPERIENCE

Mr. Ilya Pakhomov  
JSC "SSC RF – IPPE", Russia  
December 19, 2018



# MEET THE PRESENTER

Mr. Ilya Pakhomov is the Head of Laboratory in the State Scientific Center of the Russian Federation - Institute for Physics and Power Engineering named after A.I. Leypunsky (IPPE).

Since 2006, he has been charged with developing advanced sodium fast reactors as an engineer, junior researcher and head of laboratory. In 2014, he became a member of the working group on scientific and technical support of the BN-1200 project in IPPE.

Currently, he is head of laboratory - management of experiments and engineering safety of fast sodium reactors. He is responsible for research of operability elements of the core, safety issues of sodium fires and safety during interloop leaks in the sodium-water steam generators.

He is also involved in the formation of an R&D plan for the Fast Sodium Reactors.



# CONTENTS

- Introduction
- Operating experience of the BN-600 reactor power unit
  - The main characteristics of the power unit
  - The main characteristics of the core
  - The main stages of the unit operation
  - The main results of the BN-600 power unit operation
- Construction and operation of the BN-800 reactor power unit
  - The main characteristics of the power unit
  - The main stages of construction, commissioning and operation of the BN-800 power unit
- Prospects for the SFR development in Russia
- Conclusion

# INTRODUCTION (1/2)

- The report reviews the Russian experience gained in the field of sodium fast reactors (SFR), where Russia takes the lead in the world, using the example of power units with the BN-600 and BN-800 reactors.
- Sodium fast reactors development began in the 1950s of the 20th century, including the USSR. In most countries, the development of this reactor technology was subsequently suspended; however, in the USSR and Russia the SFR development has been ongoing for more than 60 years.

# INTRODUCTION (2/2)

- The results of these developments are as follows:
  - experimental fast reactor BR-5 / BR-10, located at the IPPE site in Obninsk;
  - experimental fast reactor BOR-60 operating at the RIAR site in Dimitrovgrad;
  - prototype reactor unit (RU) with the BN-350 reactor, that was in operation at the site of the Mangyshlak Atomic Energy Combine in Shevchenko / Aktau (now the Republic of Kazakhstan);
  - industrial power unit No. 3 with the BN-600 reactor, operating at the Beloyarsk NPP site in Zarechny;
  - industrial power unit No. 4 with the BN-800 reactor, put into operation at the Beloyarsk NPP site in Zarechny;
  - project of the multifunctional fast research reactor MBIR being constructed at the RIAR site in Dimitrovgrad;
  - project of a commercial power unit with the BN-1200 reactor.

# World Experience on SFR (1/2)

SFR operating lifetime (as of 08.04.2018)

No	Reactor (country)	First criticality	Shutdown	Operating life, years
<b>Research SFR</b>				
1.	EBR-I (USA)	24.08.1951	30.12.1963	12.33
2.	BR-5/BR-10 (Russia)	26.01.1959	06.12.2002	43.92
3.	DFR (UK)	14.11.1959	23.03.1977	17.33
4.	LAMPRE (USA)	01.1961	mid-1963	2.42
5.	Fermi-1 (USA)	23.08.1963	27.11.1972	9.25
6.	EBR-II (USA)	11.11.1963	09.1994	33.00
7.	Rapsodie (France)	28.01.1967	15.04.1983	16.25
8.	SEFOR (USA)	05.1969	1972	~3
9.	BOR-60 (Russia)	14.12.1969	-	49.33
10.	JOYO (Japan)	24.04.1977	-	41.00
11.	KNK-II (Germany)	10.10.1977	23.08.1991	13.83
12.	FFTF (USA)	09.02.1980	18.03.1992	12.08
13.	FBTR (India)	18.10.1985	-	32.50
14.	CEFR (China)	21.07.2010	-	7.75
<b>Total (research SFR)</b>				294.00 years
<b>Power SFR</b>				
1.	БН-350 (USSR/Kazakhstan)	29.11.1972	22.04.1999	26.42
2.	Phenix (France)	31.08.1973	12.09.2009	36.08
3.	PFR (UK)	01.03.1974	31.03.1994	20.00
4.	BN-600 (Russia)	26.02.1980	-	38.17
5.	Super-Phenix (France)	07.09.1985	12.1998	13.25
6.	MONJU Japan)	05.04.1994	21.12.2016	21.67
7.	BN-800 (Russia)	27.06.2014	-	3.83
<b>Total (power SFR)</b>				159.42
<b>Total (research and power SFR)</b>				453.42

# World Experience on SFR (2/2)

Breakdown of SFR operating lifetime by countries, years  
(as of 08.04.2018)

No	Country	Operating lifetime of research SFR	Operating lifetime of power SFR	Overall operating lifetime of SFR
1.	USSR/Russia	93.25 (31.72%)	61.08 (38.32%)	154.33 (34.04%)
2.	USA	72.08 (24.52%)	-	72.08 (15.90%)
3.	France	16.25 (5.53%)	49.33 (30.94%)	65.58 (14.46%)
4.	Japan	41.00 (13.95%)	21.67 (13.59%)	62.67 (13.82%)
5.	UK	17.33 (5.89%)	20.00 (12.55%)	37.33 (8.23%)
6.	India	32.50 (11.05%)	-	32.50 (7.17%)
7.	Germany	13.83 (4.70%)	-	13.83 (3.05%)
8.	China	7.75 (2.64%)	-	7.75 (1.71%)
9.	Kazakhstan	-	7.33 (4,60%)	7.33 (1.62%)
	<b>All countries</b>	<b>294.00 (100%)</b>	<b>159.42 (100%)</b>	<b>453.42 (100%)</b>

# Stages of SFR Technology Development



BR-5/10

(1959-2002, Obninsk)



BOR-60

(1969, Dimitrovgrad)



BN-350

(1972-1999, Aktau)



BN-600

(1980, Zarechny)



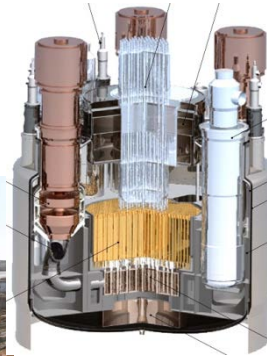
BN-800

(2014, Zarechny)



MBIR

(2016, Dimitrovgrad)



BN-1200



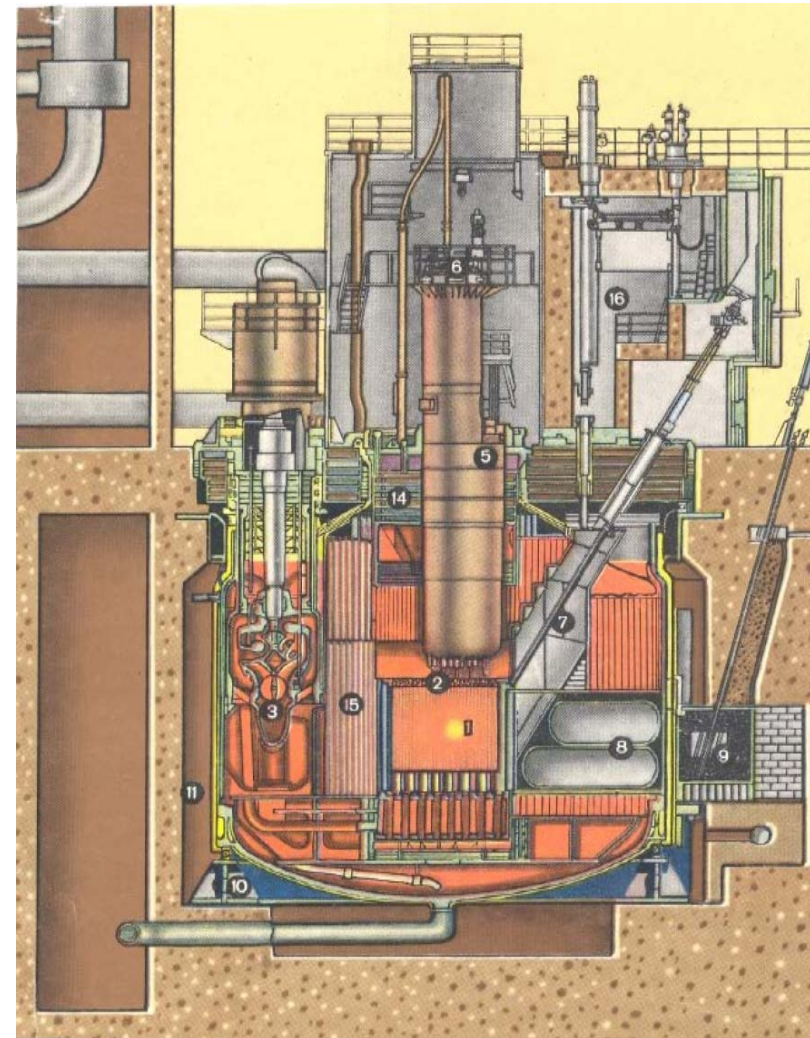
# Operating Experience of the BN-600 Power Unit (1/2)



View from the water-storage reservoir to power units No. 1-3 of the Beloyarsk NPP

# Operating Experience of the BN-600 Power Unit (2/2)

- In the course of BN-600 RU design development and engineering concept selection, all the experience accumulated at BR-5 / BR-10, BOR-60 and BN-350 was taken into account. The fundamental difference of BN-600 from the previous SFR designs is pool-type arrangement of the primary circuit. Correctness of the decisions made in the BN-600 design was later confirmed by its successful operation for almost 38 years.
- Power start-up of the BN-600 reactor took place on April 8, 1980, the design power level was reached in December 1981.
- Since 1982, BN-600 power unit 3 of the Beloyarsk NPP has been in commercial operation as a commercial power unit.



Longitudinal section of the BN-600 vessel

# Main Characteristics of the BN-600 Power Unit (1/2)

General parameters:	
Thermal power, MWth	1470
Electric power, MWe	600
Number of circuits	3 (primary and secondary circuits - sodium, 3 circuit – steam-water)
Design lifetime, year	30 (extended to 40)
Primary circuit:	
Arrangement	Pool-type
Reactor vessel support	At the bottom
Vessel cooling agent	Cold sodium
Number of heat removal loops	3
Sodium temperature at core Inlet/outlet°C	377/550
Sodium flow rate, t/h	25000
Core and fuel:	
Fuel	Uranium dioxide pellets
Max. fuel burnup, % h.a.	11.1
Diameter, mm	2058
Height, mm	1030
Intermediate heat exchanger:	Shell-and-tube design, secondary sodium flowing on the tube side

# Main Characteristics of The BN-600 Power Unit (2/2)

<b>Primary pump:</b>	Centrifugal, one stage
<b>Rotating speed, rpm</b>	250-970
<b>Steam generator:</b>	Once-through, section & modular, 8 sections (3×8=24 modules)
<b>Inlet/outlet sodium temperature, °C</b>	518/328
<b>Inlet/outlet water/steam temperature, °C</b>	241/507
<b>Life steam pressure, MPa</b>	14
<b>Secondary pump:</b>	Centrifugal, one stage
<b>Rotating speed, rpm</b>	250-750
<b>Turbo generator:</b>	Standard
<b>Power, MW</b>	210
<b>Decay heat removal system:</b>	
<b>Primary and secondary circuits</b>	Normal operation system. Bypass with AHX on loop №5 of secondary circuit
<b>Third circuit</b>	Steam generator-deaerator, emergency feedwater pumps
<b>Refueling system:</b>	2 rotating plugs, vertical refueling mechanism
<b>Fuel transfer system:</b>	Elevators with guide ramp
<b>Spent fuel storage:</b>	In-vessel storage, sodium and water pools
<b>Washing of subassemblies from sodium:</b>	Steam-gas-water

# Main Characteristics of BN-600 Core

- The program of gradual enhancement of the uranium oxide burnup design level was carried out at the BN-600 reactor.
- The first modification of the BN-600 core (01M) involved changing the fuel element and core configuration to decrease linear heat rating in fuel elements, as well as optimizing the scheme of core refueling.
- Further increase of fuel burnup was achieved by changing the structural material of the fuel element cladding and fuel assembly ducts (modification 01M1).
- The successful operation of the BN-600 reactor with the 01M1 core and the complex research work made it possible to increase the design value of fuel burnup up to 11.1% h.a. and to change over to the longer fuel element lifetime with 4-fold reactor refueling (modification 01M2).

# Evolution of BN-600 Reactor Core Characteristics

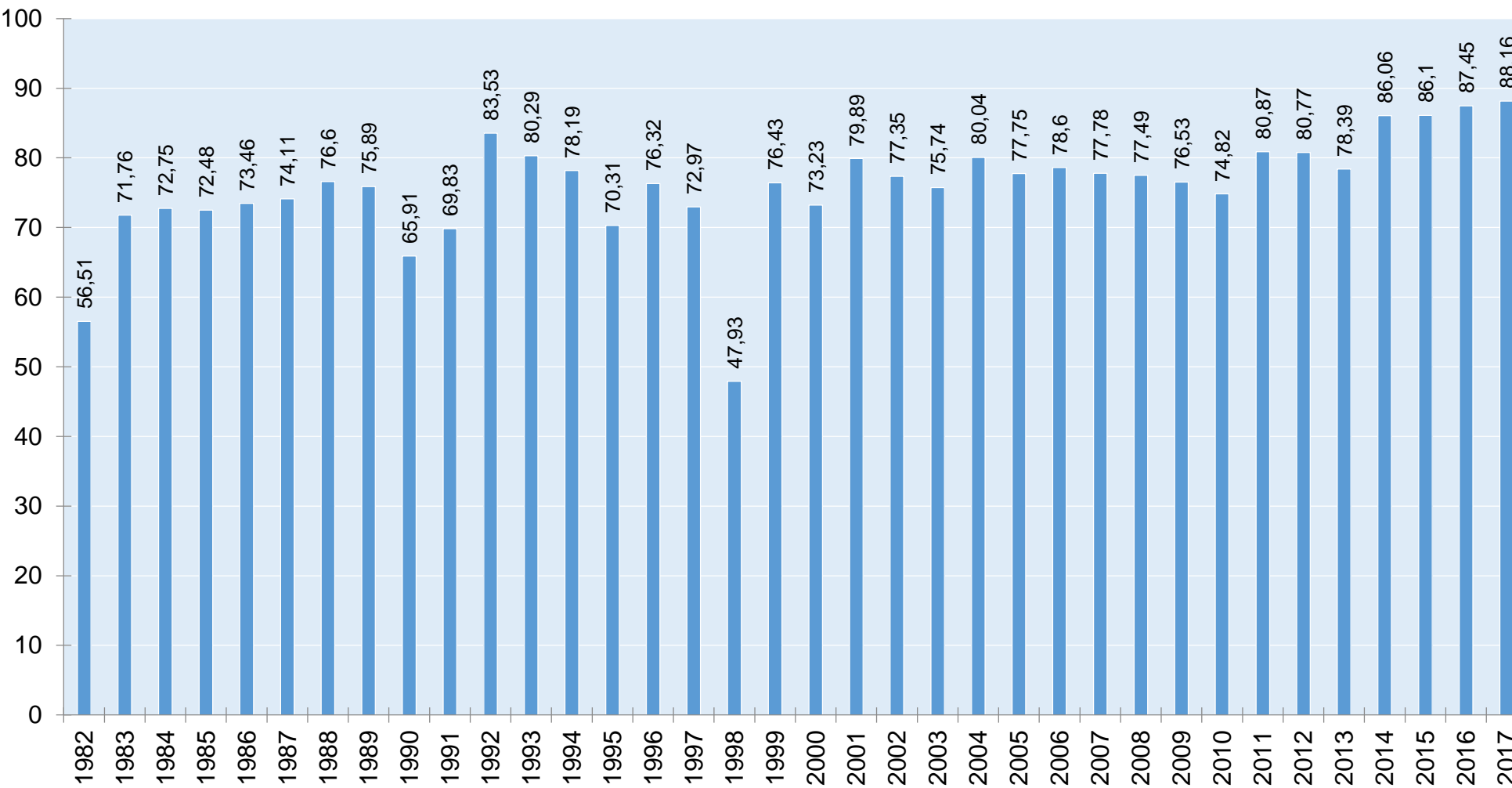
Characteristics	Reactor core modification			
	01	01M	01M1	01M2
Operating period of the core modification	1980-1986	1987-1991	1993-2004	from 2005
Reactor core height, mm	750	1000	1030	1030
Axial blankets height, mm				
- upper	400	300	300	300
- lower	400	380	350	350
Number of fuel enrichment zones	2	3	3	3
Fuel rod gas plenum length, mm	808	653	653	653
Core structural materials:				
- Cladding <sup>1)</sup>	EI-847	EI-847	ChS-68cw	ChS-68cw
- Duct	Cr16Ni11Mo3	Cr16Ni11Mo3Ti	EP-450	EP-450
Fuel rate maximum linear heat rating, kW/m	54.0	47.2	≤48.0	≤48.0
Maximum fuel burnup, % h.a.	7.2	8.3	10	11.1
Maximum radiation dose to cladding, dpa	43.5	53.9	75.0	82.0
Fuel operating life, fpd	200/300	300/495	480	560/720
Core fuel cycle, fpd	100	165	160	120/160 <sup>2)</sup>
Fuel inventory in core, kg	8260	11630	12090	12090
Average fuel burnup, MW·d/kg U	42.5	44.5	60.0	70.0

1) EI-847 - Cr16Ni15Mo3Nb – austenitic steel; ChS-68cw - Cr16Ni15Mo2Mn2TiB – austenitic steel; EP-450 - Cr12MoBnVB – ferritic-martensitic steel.

2) 120 fpd – summer fuel cycle; 160 fpd – winter fuel cycle.

# Load Factor of Beloyarsk NPP 3<sup>rd</sup> Power Unit with BN-600 Reactor

Load factor, %



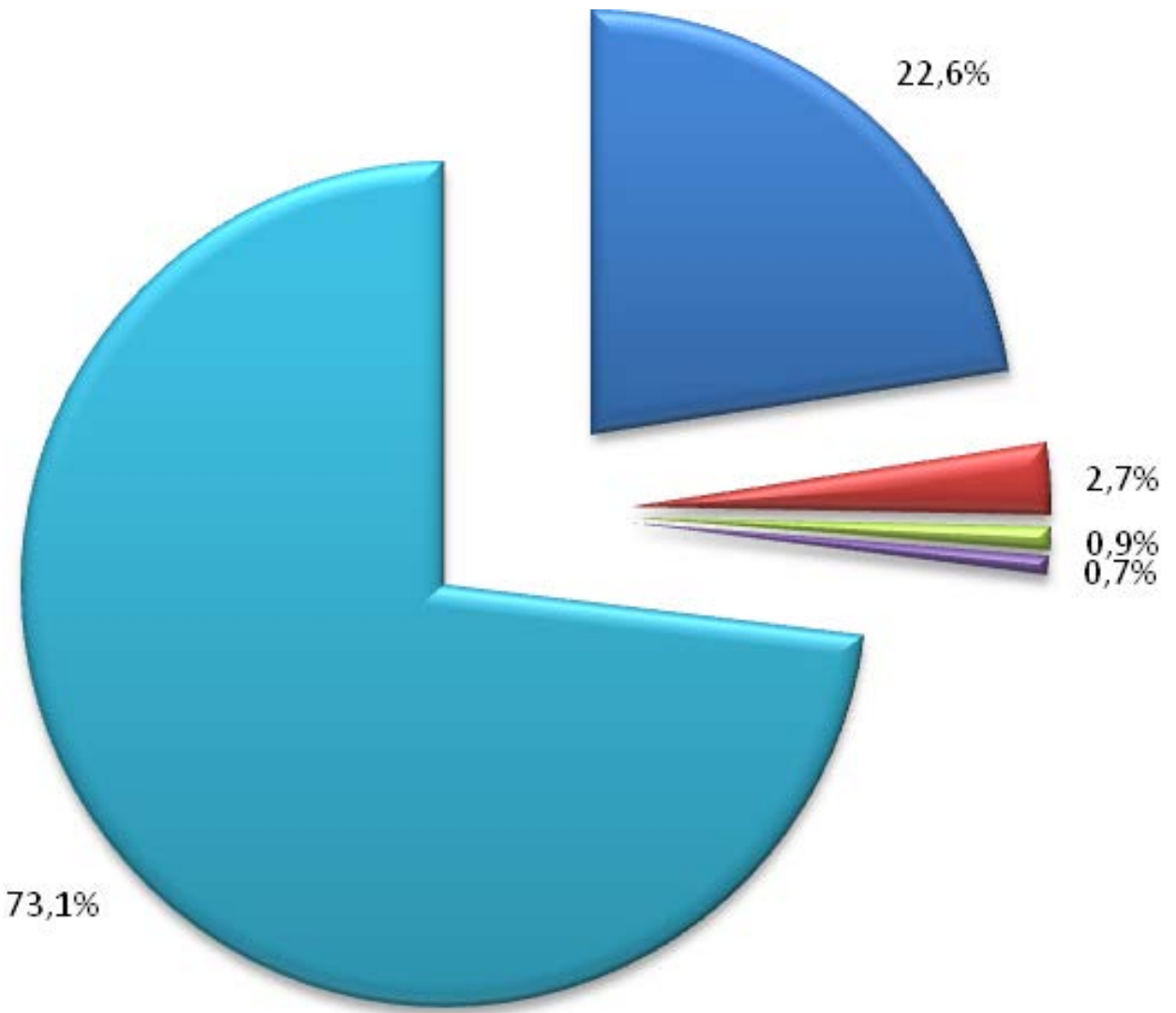
- The average load factor for the entire period of operation of the power unit till the end of 2017 equaled to 74.25%;
- For the period of commercial operation (1982-2017) it was equal to 74.55%;
- Some load factor decrease during the period from 2005 till 2010 was caused by the necessity to carry out the work on the BN-600 lifetime extension through the replacement of the equipment whose lifetime was over, specifically, steam generator modules, and modernization of safety systems, etc.

# Distribution of Reasons of Load Factor Decrease of BN-600 Power Unit (1/2)

- The results of detailed analysis of the reasons for load factor decrease of the BN-600 power unit are shown, for the period of its operation from 1982 till 2004 inclusive.
- The value of scheduled load factor decrease is caused by duration of power unit shutdown periods necessary for carrying out scheduled preventive and repair work and reactor refueling.
- Now, the duration of annual reactor shutdown period for scheduled preventive repair (SPR) is mainly determined by the rated time of complete overhaul of the turbine generators (50 days) and time required for reactor refueling (twice a year).
- In the recent years of operation, average SPR duration has been about 71 days.

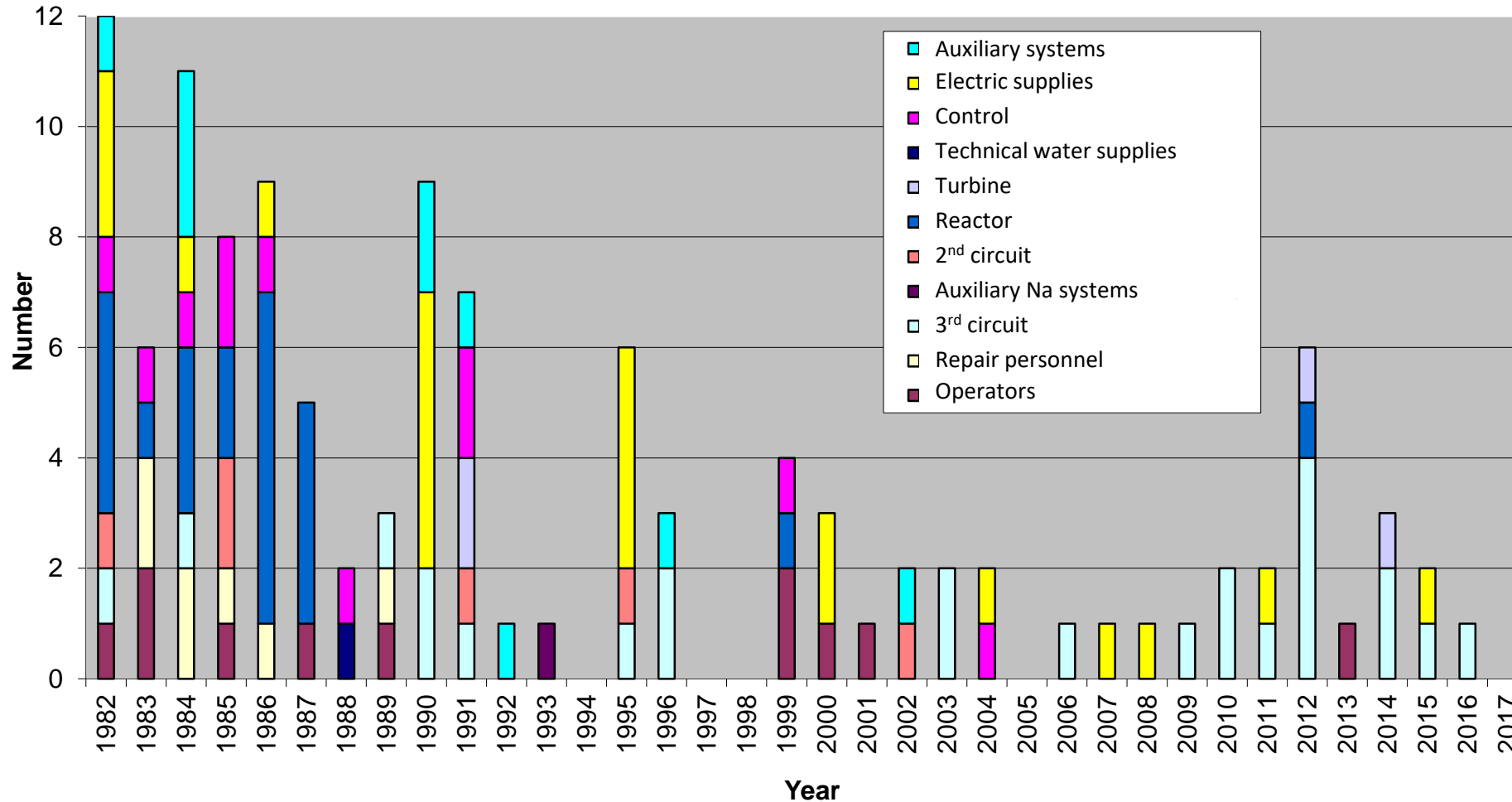


# Distribution of Reasons of Load Factor Decrease of BN-600 Power Unit (2/2)



- scheduled inspections and core refuelings;
- failures of the equipment and personnel errors;
- dispatching restrictions, decrease of the efficiency of the 3rd circuit etc.;
- heat supplies
- electric power production

# Beloyarsk NPP 3<sup>rd</sup> Power Unit with BN-600 Reactor (1/4)



Time distribution of events caused by failures of the equipment and the personnel errors during the period of the BN-600 operation

- The distribution of events caused by failures of the equipment and the personnel errors that occurred during the period from 1982 until 2017 are presented.
- After the personnel had mastered the SFR technology at the early stage of the BN-600 power unit operation and adjusted the main sodium equipment, the failures occurred mostly in electric supply systems and technological equipment of the 3<sup>rd</sup> circuit and were not connected with the sodium systems.
- On average, the unscheduled value of load factor loss is equal to 1.1% per year.

# Beloyarsk NPP 3<sup>rd</sup> Power Unit with BN-600 Reactor (2/4)

The achieved parameters on operation time and lifetime of the SFR equipment without overhaul, hours

Component	Operating time without overhaul, hours
<b>Non-replaceable equipment:</b>	
Reactor vessel	205 000
Primary circuit pipings	205 000
Sodium pumps	105 000
Intermediate heat exchangers	205 000
Steam generators (evaporators)	125 000

- The presented data testify to good compatibility of sodium coolant with structural materials used and its low corrosion activity in the mastered range of SFR parameters.
- The replacement of the following main equipment of the BN-600 power unit was implemented during its operation:
  - 4 sets of the primary sodium main circulating pumps;
  - 1 set of the secondary sodium main circulating pumps;
  - 1 set of mechanisms of the control and protection system (CPS);
  - 3 sets of guide tubes of CPS rods;
  - Full set of SG modules + 1 set of SG evaporator modules;
  - 1 intermediate heat exchanger.
- The unique repair work was performed on the small rotating plug.

# Beloyarsk NPP 3<sup>rd</sup> Power Unit with BN-600 Reactor (3/4)

The main characteristics of large sodium leaks at BN-600

Date of leak	Place of leak	Detection method	Causes	Amount of sodium leaked
13.01.80	Sodium reception system	Ionization smoke detector	Defects of flange joints	50 kg
11.08.81	SG valve seal	Electric heating control, ionization detectors	Defects of flange joints	300 kg
02.07.82	SG valve seal	Personnel visual inspection	Defects of flange joints	30 kg
31.12.90	SG drainage line	Electric heating	Manufacture defects	600 kg
07.10.93	Primary sodium purification system	Electric heating, radioactive aerosol detection	Insufficient homing action of pipelines	1000 kg
06.05.94	Drainage line of intermediate heat exchanger	Personnel visual inspection	Cutting the pipe before sodium freezing	650 kg

- All 27 sodium leaks that occurred at the early stage of the BN-600 reactor operation were mostly small leaks:
  - In 21 leaks the amount of sodium leaked didn't exceed 10 L (from 0.1 to 10 L).
- In 6 other leaks the amount of sodium leaked was 30, 50, 300, 600, 650 and 1000 L.

The experience in sodium leaks outside and inter-circuit leaks in SG was gained at the early stage of the BN-600 operation (when the personnel mastered the SFR technology, tested and optimized the design solutions, adjusted operation modes, detected defects in manufacture of equipment.)

# Beloyarsk NPP 3<sup>rd</sup> Power Unit with BN-600 Reactor (4/4)

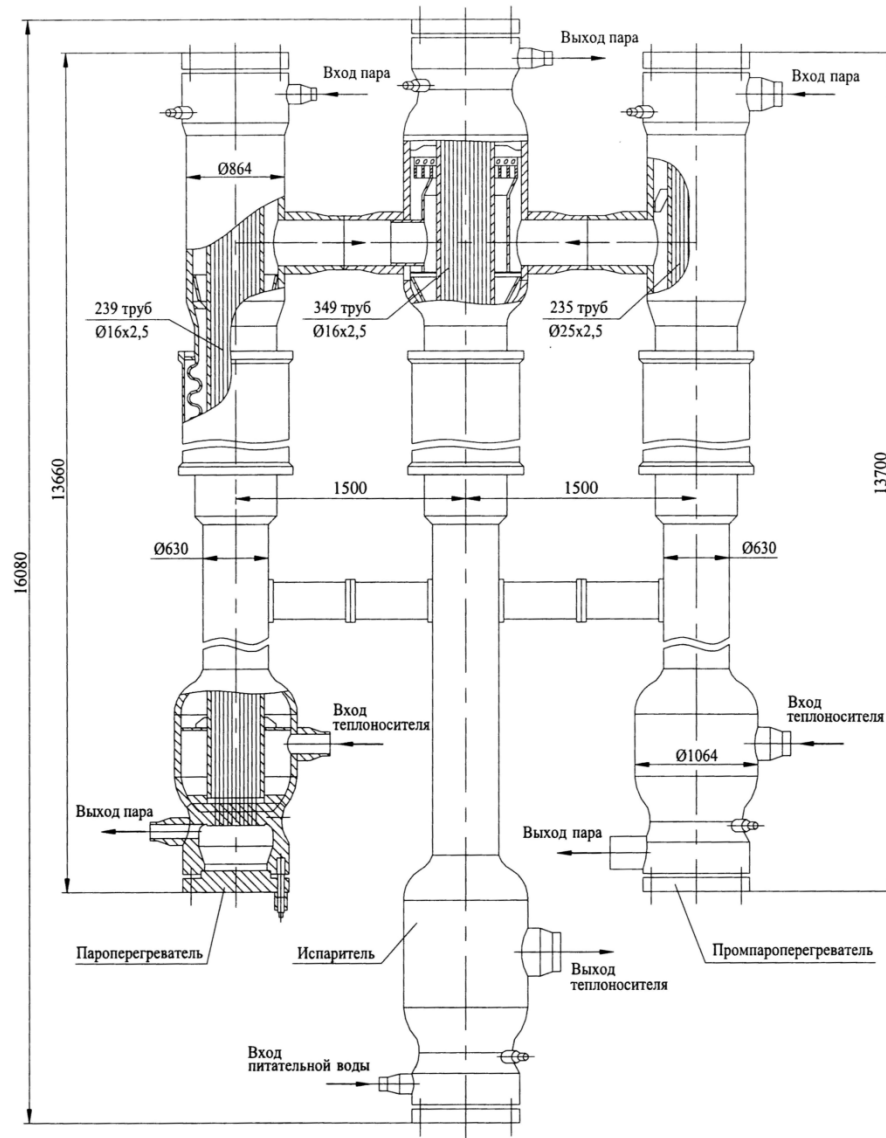


- All the 27 sodium leaks were detected in due time by detection systems or operators.
- There were 14 cases of sodium fires.
- Powders were used for confining and extinguishing non-radioactive sodium fires.
- The design algorithm of sodium fire consequences confinement was implemented only in one case of radioactive sodium leak from the primary circuit, and it proved its value: the radioactivity release of 10.7 Ci caused by this incident was well below the permissible limit.
- The accumulated sodium leaks experience proved the effectiveness of the protection systems aimed at leak consequences confinement.
- Total number of leaks can be distributed with respect to the reactor facility components in the following way:
  - Sodium reception system – 5
  - Cut-off valves of SG modules – 5
  - Auxiliary secondary systems – 12
  - Auxiliary primary systems – 5
- The last sodium leak at the BN-600 reactor took place 24 years ago, in May, 1994.

# BN-600 Steam Generator

- The sectional/modular steam generators used in the BN-600 reactor have demonstrated high performance characteristics for the whole period of power unit operation.
- During the whole period of SG operation, 12 leaks have occurred. All these leaks took place in the early stage of the unit operation.
- Half of the 12 leaks of steam and water into sodium happened in the first year of operation because of manifestation of hidden manufacturing defects.
- Intercircuit leaks took place mainly in the modules of superheaters (6 events) and reheaters (5 events), while only one leak occurred in the evaporator.
- All the listed SG leaks were suppressed by regular means, and did not result in emergencies.
- During the last 33 years of operation, there was only one minor SG leak that happened in January, 1991.
- The SGs have operated without any intercircuit leaks for 27 years, despite numerous replacements of SG modules that were performed during this period as part of the power unit life extension procedures.

# BN 600 Steam Generator Section



- The BN-600 steam generator section consists of 3 modules:
  - evaporator
  - superheater
  - reheater
- The steam generator of each coolant loop consists of 8 SG sections connected in parallel

# Characteristics of Intercircuit Leaks in BN-600 Power Unit SG Modules

Parameters at the time of leak	No. of leak											
	1	2	3	4	5	6	7	8	9	10	11	12
Module	RH	SH	RH	SH	SH	SH	SH	SH	EV	RH	SH	RH
Date of leak	24.06.80	04.07.80	24.08.80	08.09.80	20.10.80	09.06.81	19.01.82	22.07.83	06.11.84	10.11.84	24.02.85	24.01.91
Leak rate, g/s	0.02-6	0.1-0.615	0.09-15	0.2-0.3	0.0064-0.23	140	250	-	0-3	0.02	0.14	4.6
Amount of water escaped into 2 circuit, kg	40	17.87	7	0.18	0.78	40	20.3	2.77	1.8	0.75	0.73	8.3

EV – Evaporator, SH – Superheater, RH – Reheater

- Evaluating all the deviations from normal operating mode that took place during the BN-600 operation, including those connected with sodium leaks, it should be emphasized that none of them resulted in any radiation impact on the population and environment. By the off-site impact criteria, all of them are below the International Nuclear Event Scale, and, therefore, are insignificant.



# Key Results of BN-600 Power Unit Operation (1/2)

- During the operation of the BN-600 power unit, the following goals were achieved:
  - Long-term endurance tests of large-size equipment operating in sodium.
  - Mastering the sodium technology on an industrial scale.
  - Development and optimization of operating modes.
  - Mastering the technology of replacement and repair of sodium equipment including the primary components (pumps, steam generators, intermediate heat exchangers, rotating plugs).
  - Reaching the acceptable level of fuel burnup.

# Key Results of BN-600 Power Unit Operation (2/2)



- During the entire period of its operation (as of the end of 2017, 265 707 hours in critical state), BN-600 produced more than 147.4 billion kWh of electrical energy, making a notable contribution into the Urals power supply as one of the most cost-effective and eco-friendly power units:
  - Amount of gaseous radioactive products emission to the atmosphere, as a rule, does not exceed 1% of the acceptable level.
  - Amount of solid and liquid radioactive waste is also minimal, not exceeding 50 m<sup>3</sup> per year.
  - Personnel radiation exposure is lower than the average level existing in the nuclear industry.
- One of the most important results obtained during the BN-600 operation is the fact that the design parameters for sodium large-scale equipment operation period and life time have been achieved and even exceeded.
- During the period of industrial operation the BN-600 reactor demonstrated high safety and reliability characteristics and thus solved its task which was to industrially justify the reliability and safety of the SFR technology and, specifically, the technology of sodium coolant.

# BN-600 Life Extension

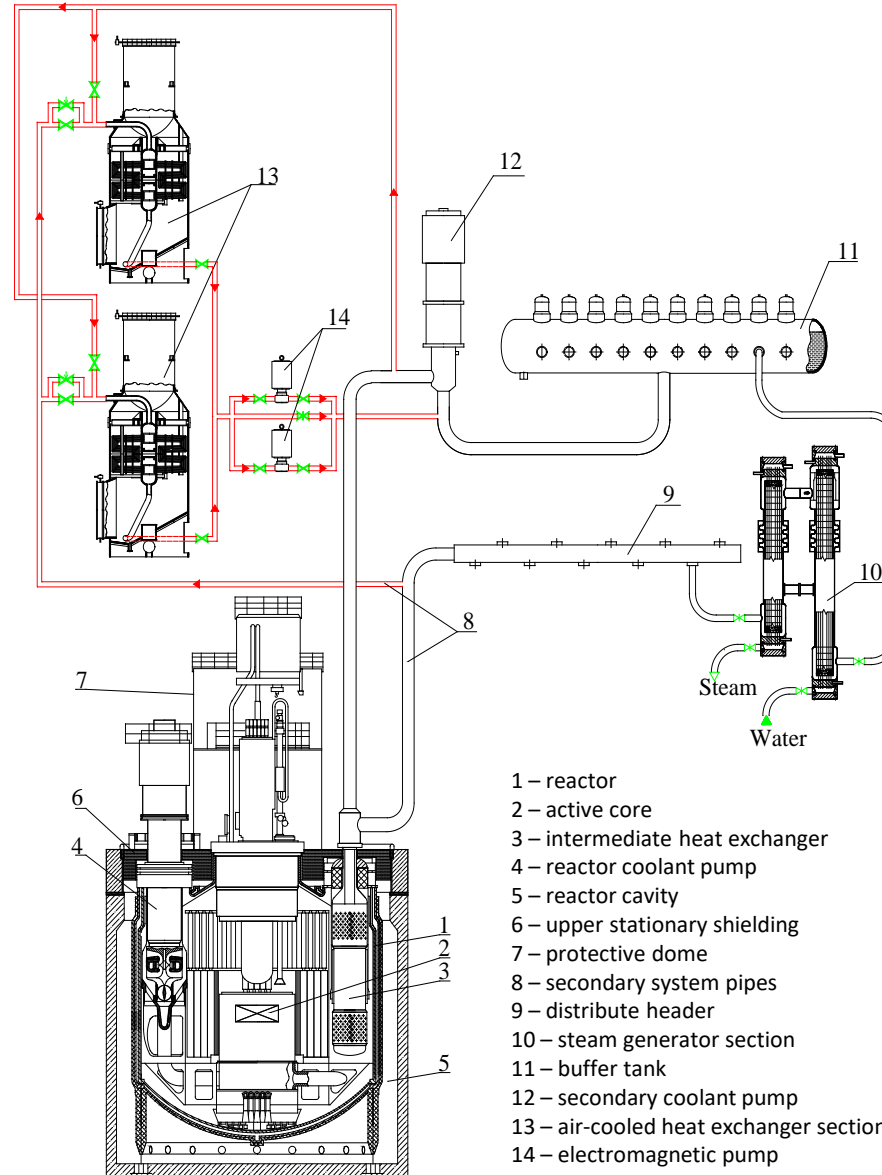
- The 30-year design lifetime of BN-600 was to be over in 2010. In 2005–2010, the activities were performed to extend the BN-600 life time for 10 years, up to March 31, 2020. It should be noted that the obtained results showed the possibility to extend the BN-600 lifetime to 45 years.
- Currently, activities are under way to extend the BN-600 life time beyond the year 2020. Preliminary results prove the principal technical possibility of extending the BN-600 reactor lifetime to 60 years.

# Power Unit with BN-800 Reactor (1/3)

- One of the main problems that has to be solved in the process of BN-800 operation is the demonstration of closed nuclear fuel cycle.
- Organizing the closed nuclear fuel cycle with a SFR will indicate mastering the SFR technology in its entirety.
- Over the long term, this will address the issues of expanding the nuclear fuel base and disposal of spent nuclear fuel, including minor actinides.

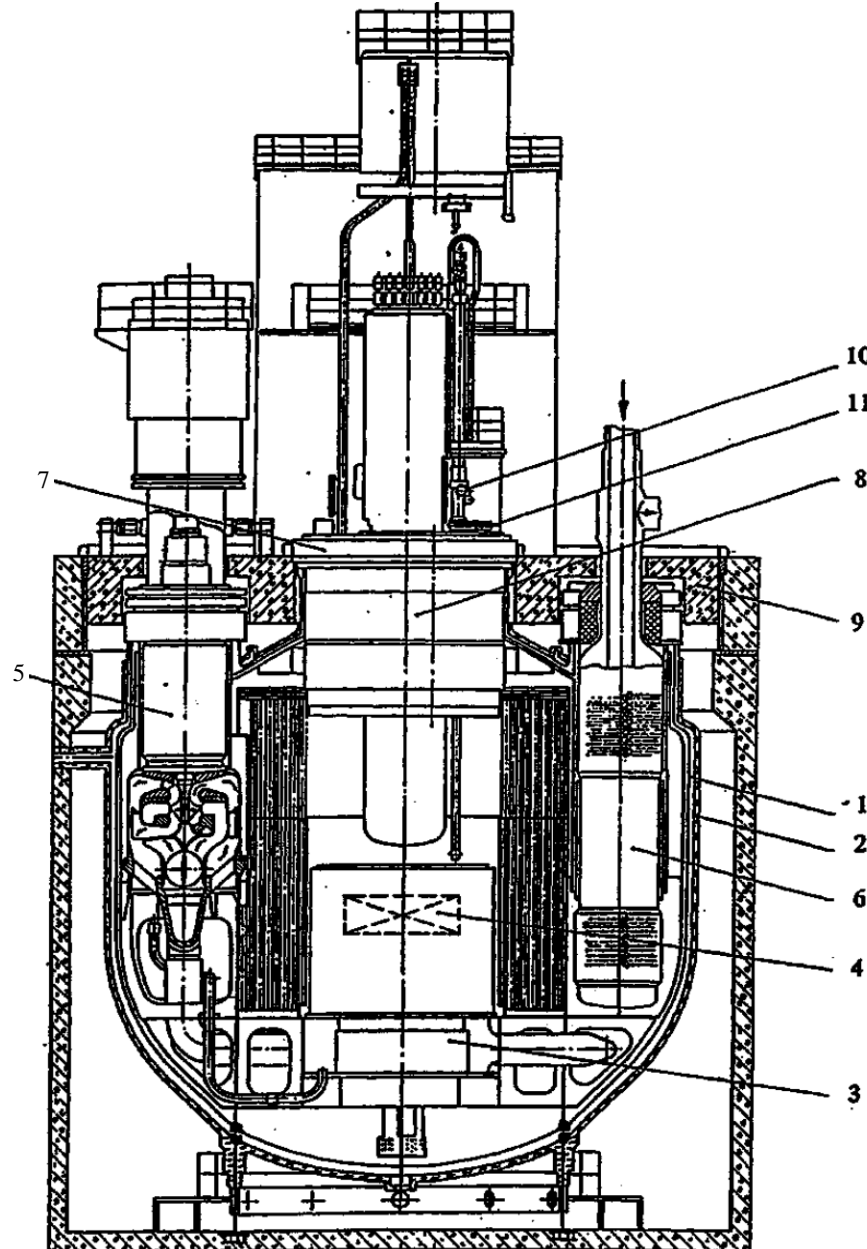
# Power Unit with BN-800 Reactor (2/3)

- Currently a hybrid core is used in the BN-800 reactor; it includes both MOX-fuel and enriched uranium dioxide-fuel assemblies.



General scheme of a nuclear steam-supply system (NSSS) with BN-800 reactor

# Power Unit with BN-800 Reactor(3/3)



Longitudinal section of the BN-800  
reactor:

1-main reactor vessel, 2-guard vessel, 3-core diagrid, 4-reactor core, 5-reactor coolant pump, 6-intermediate heat exchanger, 7-large rotating plug, 8-above core structure, 9-upper stationary shield, 10-refuelling mechanism, 11-small rotating plug.

# Main Characteristics of BN-800 Power Unit (1/3)

Parameter	Value
<i>General Data:</i>	
Reactor thermal power, MW	2100
Electrical power, MW	880
Unit net efficiency, %	40
Operating power variation range, % nominal	17-100
Equipment seismostability, MSK-64 units	7
Operation life, year	40
Breeding ratio, year	1,04
<i>Primary system:</i>	
Coolant temperature, core inlet/outlet, °C	354/547
Cover gas pressure, MPa	0,054
Gas plenum volume, m <sup>3</sup>	110
Reactor vessel coolant mass, t	1000
Coolant flowrate, kg/cs	8600
Pump delivery head, MPa	0,82
Number of circulating pumps	3

# Main Characteristics of BN-800 Power Unit (2/3)

<i>Reactor core:</i>	
Equivalent core diameter, m	2.56
Core height, m	0.88
Average core power density, MW/m <sup>3</sup>	450
Number of core fuel assemblies	565
Fuel assembly duct width across flats, mm	96.0
Fuel assembly pitch, mm	100
Fuel	MOX sintered pellets
Initial core MOX-fuel inventory, kg	15880
Average Pu content in new fuel, %	20.5
Fertile material inventory (initial), kg	13810
Number of fuel rods per assembly	127
Fuel cladding outer diameter, mm 6.9	6.9
Fuel rod linear heat rating (max.), kW/m	48,5
Average fuel burnup, MW·d/kg	67
Maximum fuel burnup, % ha	9.9
Core lifetime, ed	465
Core refueling interval, ed	155



# Main Characteristics of BN-800 Power Unit (3/3)

<b><i>Reactor main vessel:</i></b>	
Outer diameter, m	12.96
Overall height, m	14.0
Weight (empty), tons	216
Structural material	Stainless steel Cr18Ni9
<b><i>Secondary loop:</i></b>	
Secondary coolant temperature, SG inlet/outlet, °C	505/309
Secondary circuit sodium mass (three loops), t	980
Gas plenum volume (nominal power), m <sup>3</sup>	20
Gas plenum pressure, MPa	0.245
Pump delivery head, MPa	0.42
Coolant flowrate, kg/s	2780
Number of SG sections	10
Number of DHR air cooler sections	2
Number of DHR electromagnetic pumps	2
Number of main circulating pumps	1
<b><i>Tertiary circuit:</i></b>	
Main steam pressure, MPa	13.7
Steam mass flowrate, kg/s	876
Feedwater temperature, °C	210
Main steam temperature, °C	490

# Principal Stages of BN-800 Construction and Commissioning (1/3)



- The BN-800 reactor design is to a significant extent a logical development of the BN-600 reactor and contains its main design, scientific and engineering solutions. Nevertheless, the BN-800 design has a number of conceptually new things that differ it from the BN-600 reactor.
- The principal differences are the following:
  - A passive emergency shut-down system with hydraulically suspended rods;
  - A special sodium cavity over the core to reduce sodium void reactivity effect;
  - A core catcher in the low part of the reactor vessel to collect and retain core debris under the conditions of heavy accidents;
  - A decay heat removal system dissipating heat outside through air heat exchangers connected to the secondary circuit at the SG by-pass;
  - One turbine generator for all the three heat-removal loops;
  - In SG sections a reheater module is eliminated (now it is steam reheating), so each SG section comprises an evaporator module and a primary superheater module.

# Principal Stages of BN-800 Construction and Commissioning(2/3)

## Principal stages of BN-800 unit construction, commissioning and operation

June 27, 2014	BN-800 reactor first criticality
July 30, 2015	Completion of the first criticality stage
November 10, 2015	Onset of the power start-up stage
December 10, 2015	First connection of the turbine generator to the grid
February 10, 2016	Completion of the power start-up stage
February 20, 2016	Onset of the pilot operation stage
September 2016	Completion of the pilot operation stage and preparation for power unit commissioning
October 31, 2016	BN-800 power unit commissioning

- During the whole period of its operation (as of the end of 2017) the BN-800 reactor was critical for 14 543 hours, having generated over 9.4 billion kW·h of electric power.
- The average capacity factor during the whole period of its operation till the end of 2017 was equal to 59.83%, with this value equal to 71.82% in 2017.

# Principal Stages of BN-800 Construction and Commissioning(3/3)

Power unit No. 4 with BN-800 reactor, 2008.

Power unit No. 4 with BN-800 reactor, 2014.



The view of the reactor pit under construction

Mounting of the reactor vessel bottoms

Central hall. Beginning of the FA loading

The view of power unit No. 4 with BN-800 during the daytime and at night



Main control room. Achievement of minimum controllable power.

# Prospects for Further SFR Development in Russia

- In compliance with further objectives in development and improvement of SFR technologies, the following stages can be highlighted:
  - Demonstration of BN-reactor closed fuel cycle (with BN-800 as an example);
  - SFR technology commercialization stage (designing and construction of BN-1200 commercial reactor);
  - Large-scale SFR technology development stage (construction of a small series of commercial power units with BN-1200 reactors).

# CONCLUSION

- The overview of the experience in operation of power units with BN-600 and BN-800 reactors and, particularly, the results of successful and stable operation of the third power unit at the Beloyask NPP, presented in these slides, makes it possible to draw a conclusion about the industrial development of SFR technology and, in particular, sodium technology.
- The experience gained in the course of BN-600 operation formed the basis for designing high-power sodium fast reactor BN-1200.



# Upcoming webinars

- |                  |  |   |
|------------------|--|---|
| 30 January 2019  | Scientific and Technical Problems of Closed Nuclear Fuel Cycle in Two-Component Nuclear Energetics | Dr. Alexander Orlov, IPPE, Russia               |
| 19 February 2019 | Safety of Gen IV Reactors  | Dr. Luca Ammirabile, European Commission        |
| 20 March 2019    | The ALLEGRO Experimental Gas Cooled Fast Reactor Project   | Dr. Ladislav Belovsky, UJV a.c., Czech Republic |