РОС
ЭНЕРГО
АТОМ
ЭЛЕКТРОЭНЕРГЕТИЧЕСКИЙ ДИВИЗИОН РОСАТОМА

РОСЭНЕРГОАТОМ
БЕЛОЯРСКАЯ АЭС

The first of a kind new generation power unit BN800. Commissioning features

Orator: Ivan I. Sidorov
Director
2016

Mastering the fast reactor technology

BR-5/10
1959

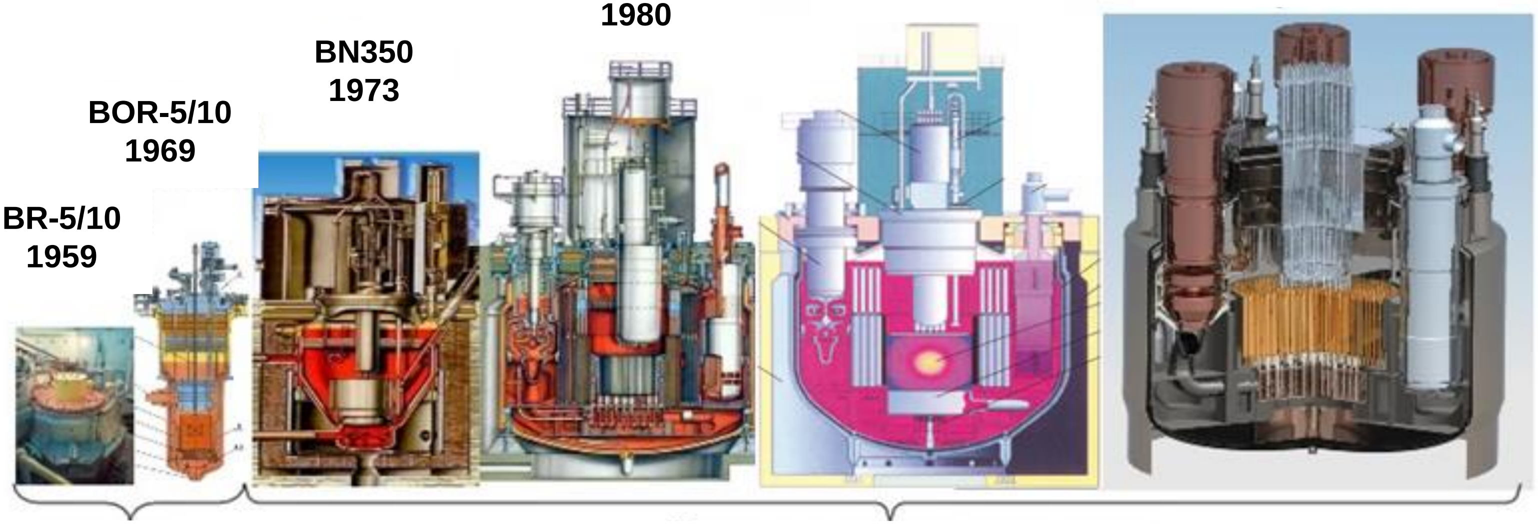
BOR-5/10
1969

BN350
1973

BN600
1980

BN800
2015

BN1200
Under development



Experimental reactors

Power reactors

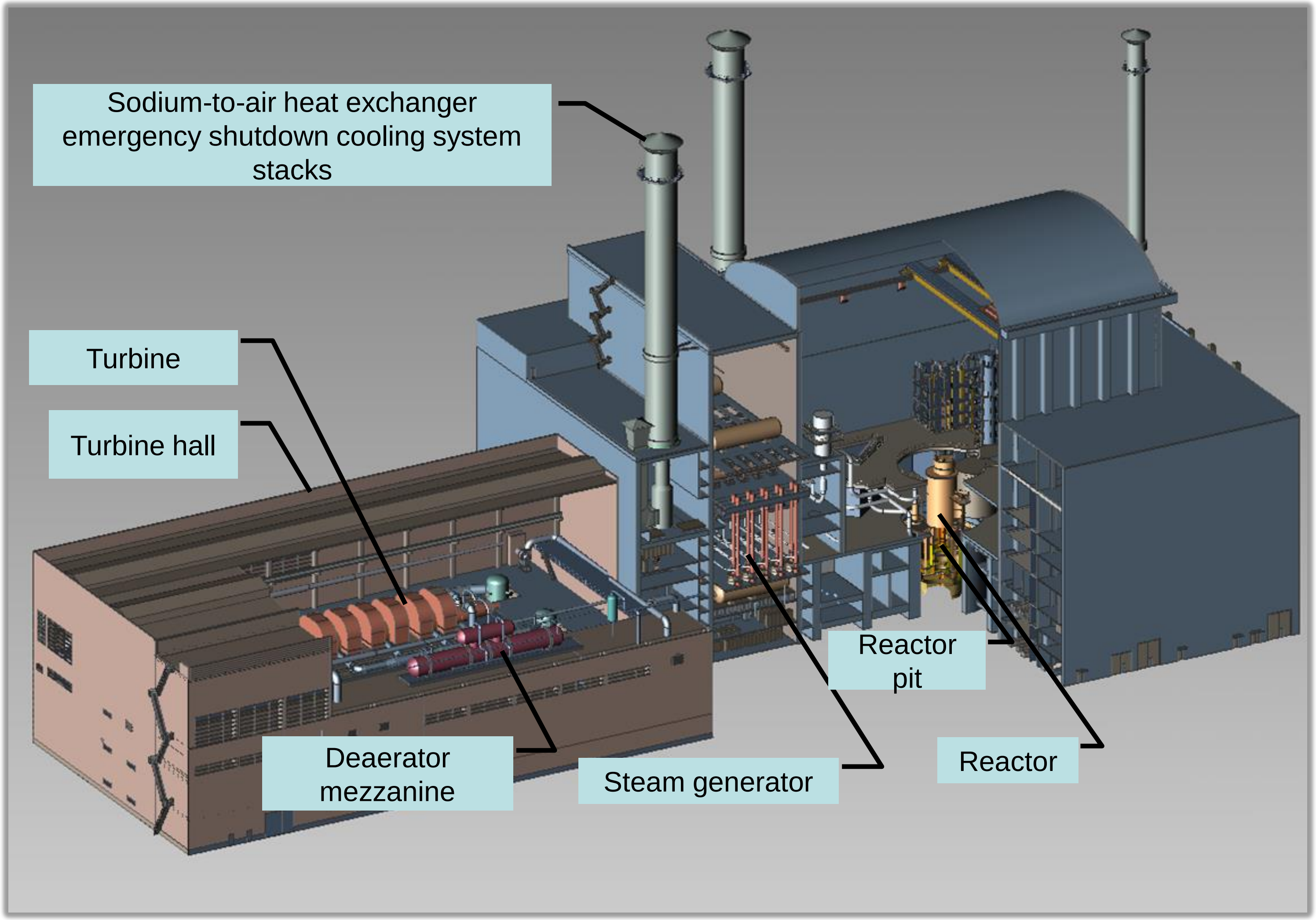
Main technical characteristics of the power unit

1	Power, MW	
	thermal	2100
	electric	880
2	Fuel	uranium, MOX
3	Coolant temperature, ^{0}C	
	at inlet of the core	354
	at inlet of the intermediate heat exchangers on primary sodium side	547
	at outlet of the intermediate heat exchangers on secondary sodium side	505
4	Superheated steam temperature, ^{0}C	490
5	Superheated steam pressure, MPa	13.7
6	Reactor vessel inner diameter, m	12.9
7	Vessel height, m	15
8	Specific metal content of the reactor, t/MWe)	9.7

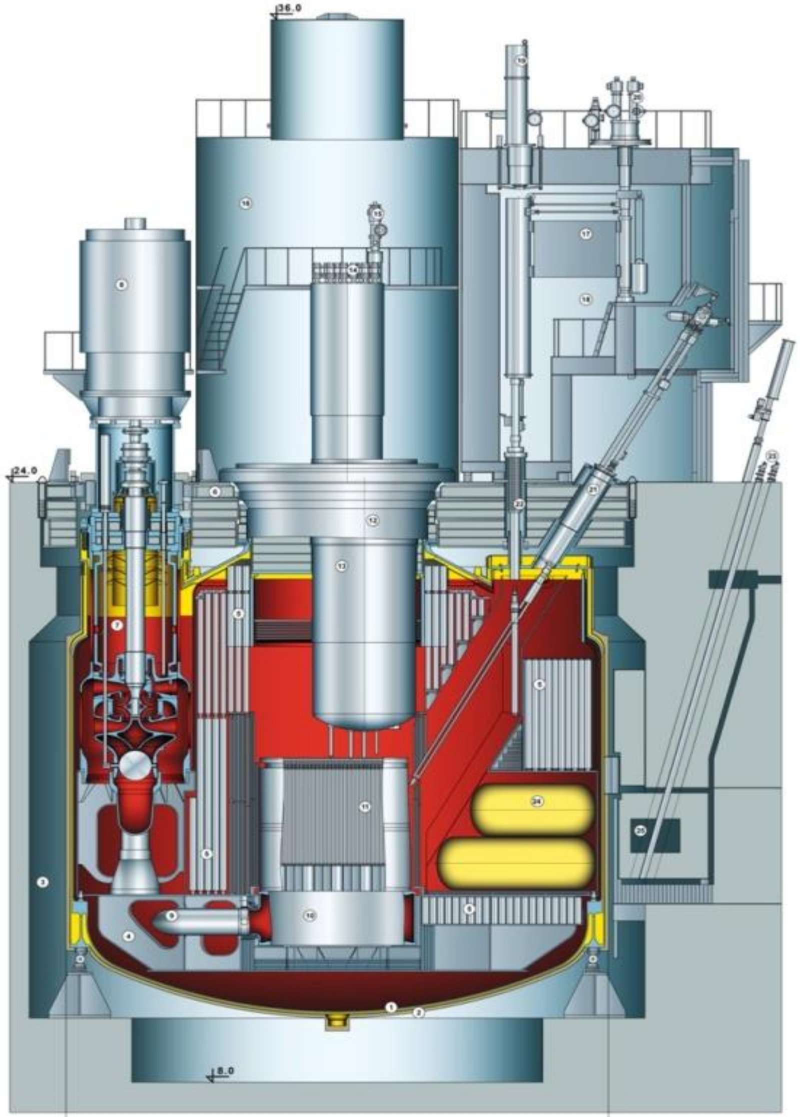
Power unit performance indicators

1	Annual net electric generation, mn kW-h	5 522
2	Net heat cogeneration, thou.Gcal	595
3	Quantity of hours of installed power utilization, h/yr	7 000 (capacity factor: 85%)
4	Net efficiency of the power unit, %	39.40
5	Lifetime, yr	40

BN800. Unit model



BN800. Design solutions



pool configuration, three-circuit layout with pressure directionality from water-steam to primary circuit

compact core, negative reactivity coefficients, small initial reactivity margin

low pressure in the reactor vessel (close to atmospheric one)

high sodium heat capacity, absence of the phase transitions

large margin to sodium boiling (above 300 °C)

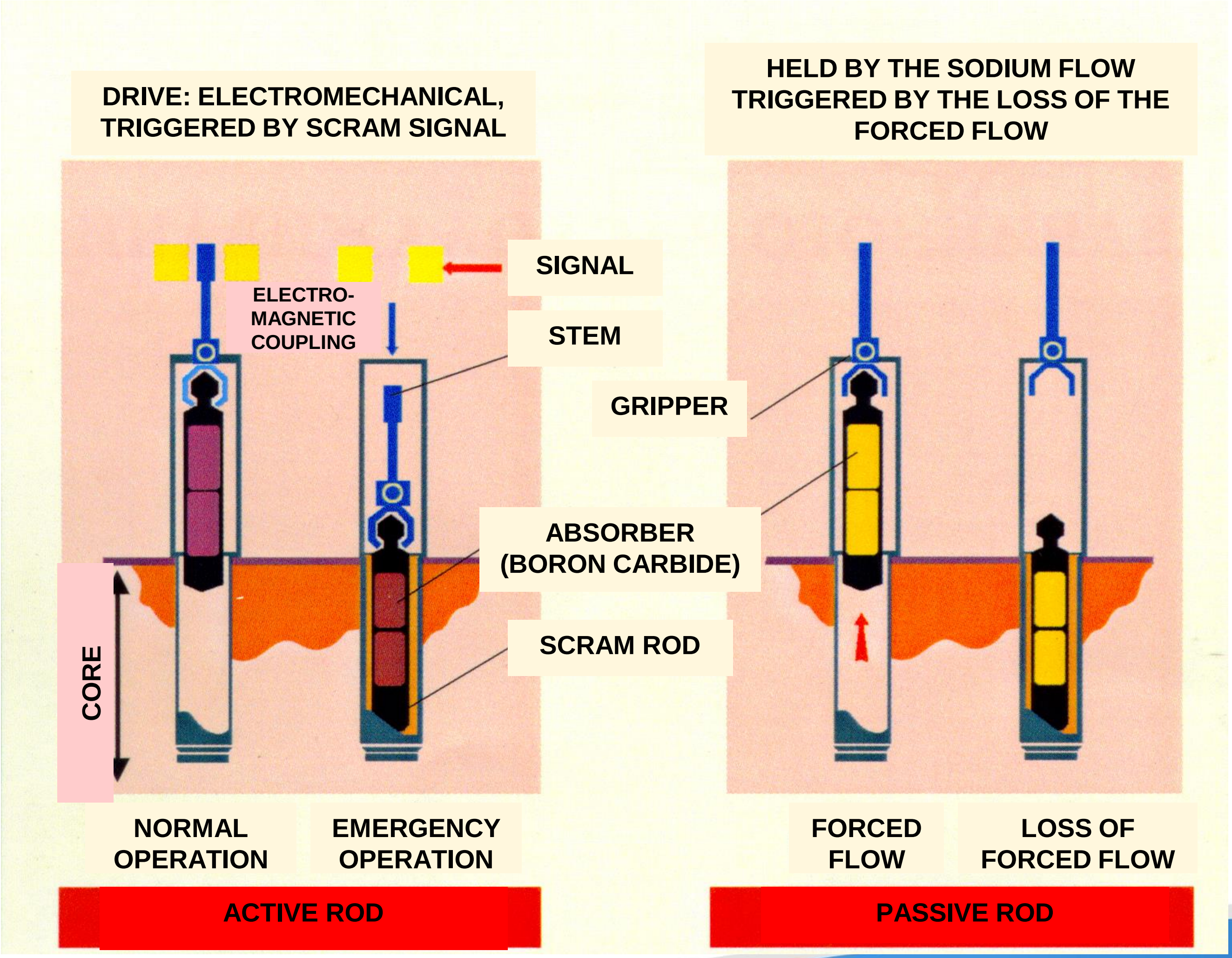
well-developed natural circulation

BN800. Solutions on the safety improvement

- ✓ The air emergency reactor heat removal system based on passive operating principles (natural flow) is provided for. Two independent reactor heat removal systems (steam generator and sodium-to-air heat exchanger emergency shutdown cooling system) based on diverse operating principles are arranged, each having got three trains.
- ✓ The reactor emergency protection system is complemented by the passive components (three independent reactor shutdown systems based on diverse operating principles).
- ✓ Corium trap for the beyond-the-design-basis accidents involving fuel melting

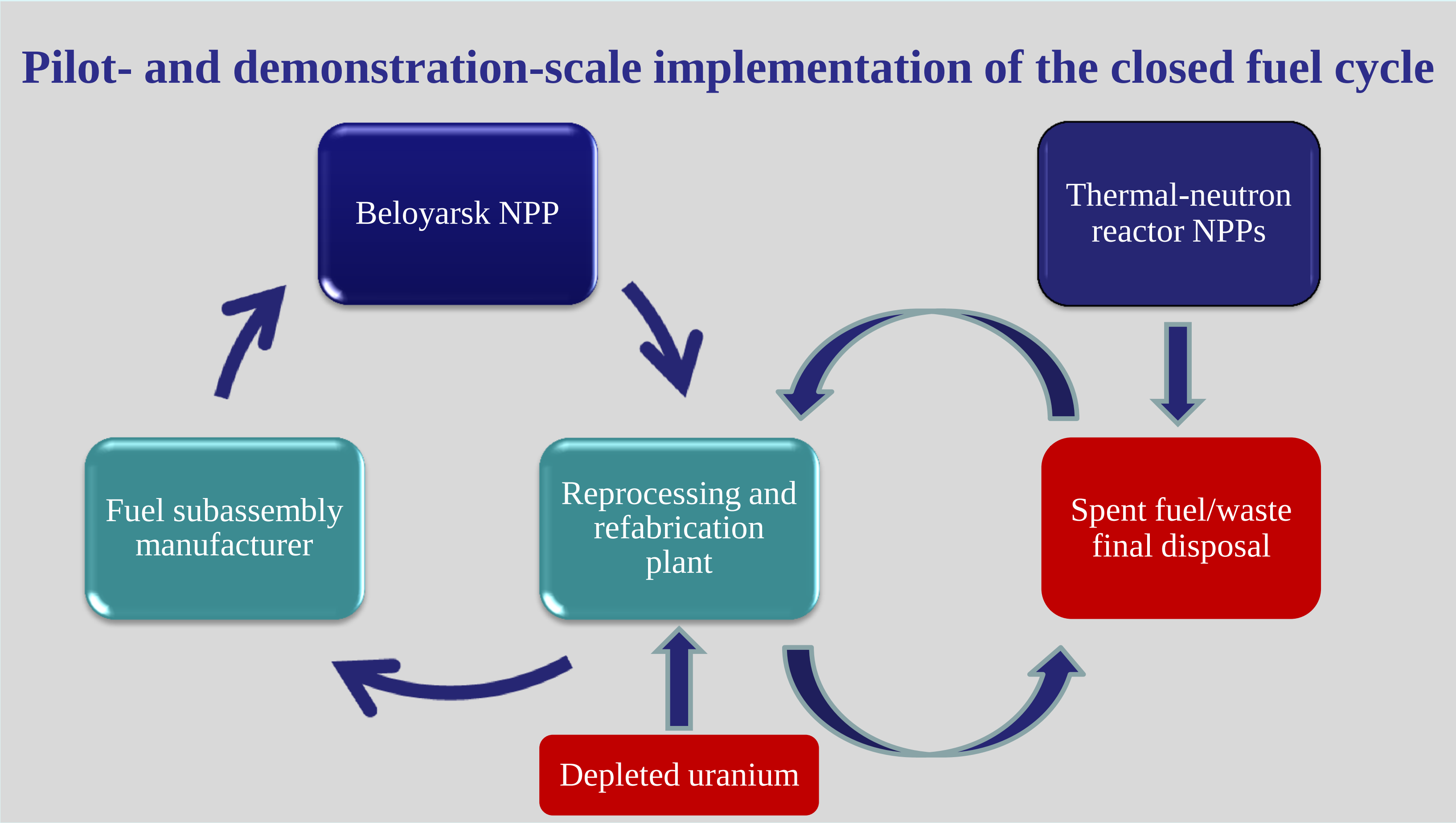
The adopted engineering and design solutions make public evacuation in case of the beyond-the-design-basis accidents unnecessary.

BN800. Utilization of the passive shutdown systems



In the BN800 reactor core in addition to the control rods, shim rods and scram rods three passive scram rods are provided for.

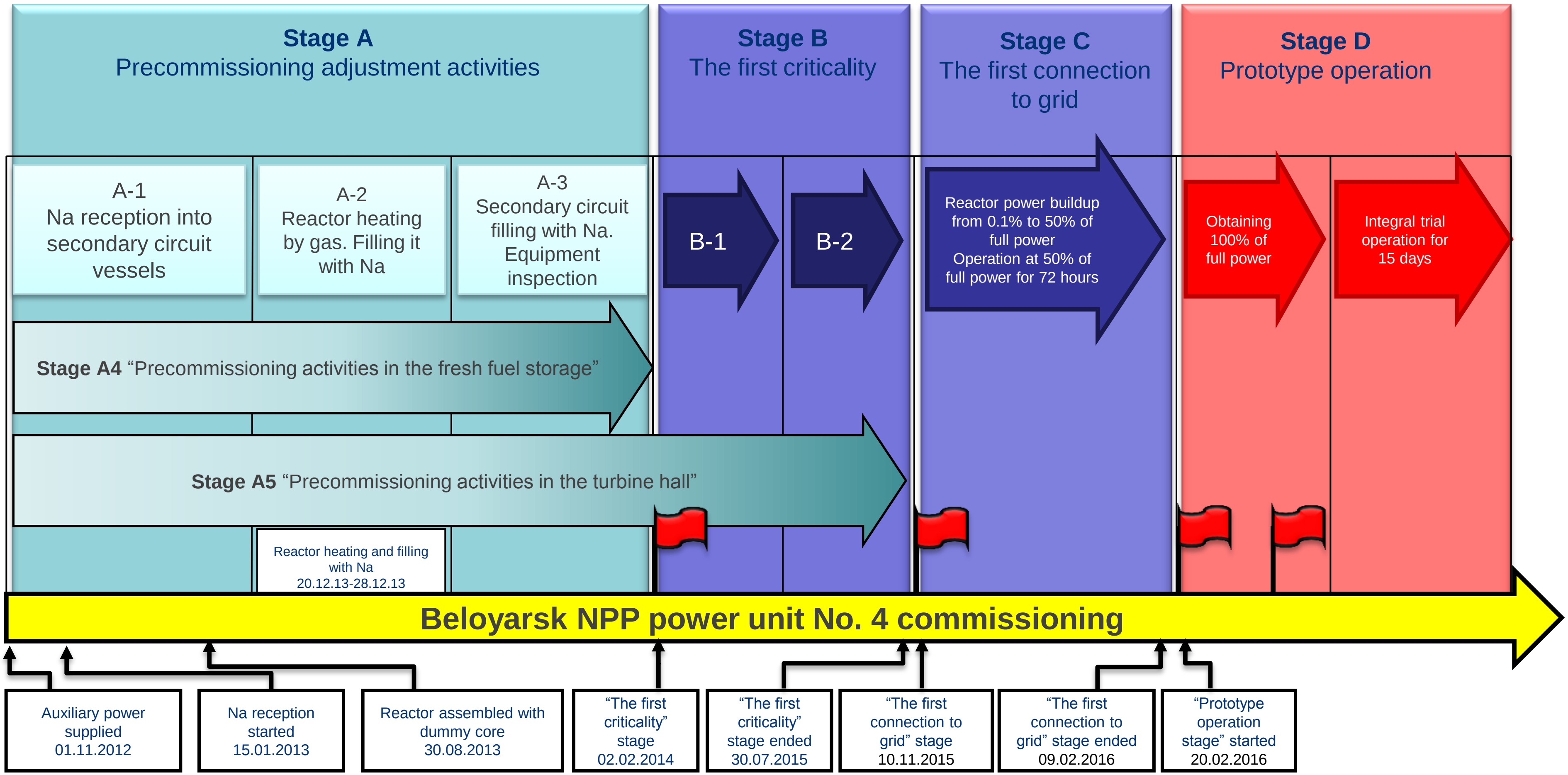
Tasks solved using BN800



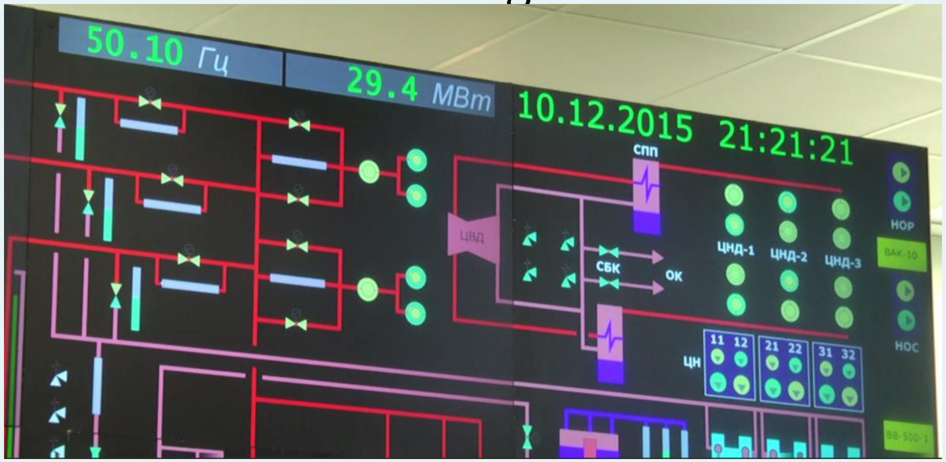
Including research in support of the feasibility of high level waste activity lowering in the long-term

Beloyarsk NPP power unit No. 4 commissioning features

Beloyarsk NPP unit No. 4 commissioning sequence



Key events in 2015 and 2016

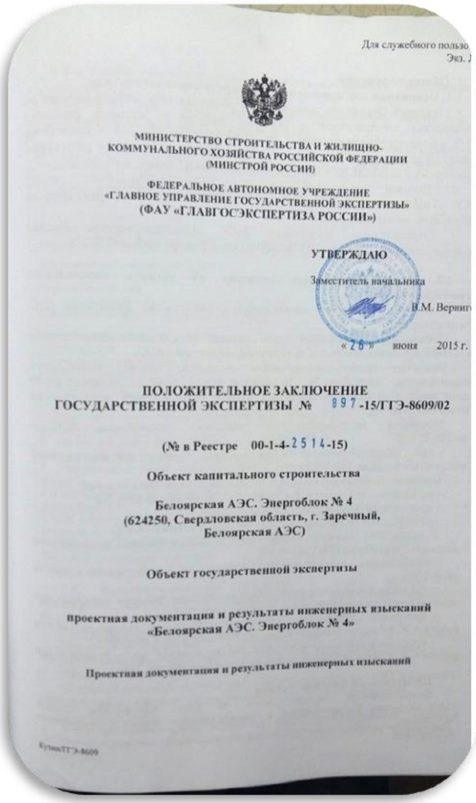
No.	Key event	Date
1	Completion of the “First criticality stage”	30.07.2015
2	Beginning of the “First connection to grid” stage	10.11.2015
3	The first connection to grid 	10.12.2015
4	Beginning of the “Prototype operation” stage	20.02.2016

Power unit No. 4 commissioning status as of March 31, 2016

No.	Indicator	Characteristic
1	Commissioning stage	**Prototype operation**
2	Construction/installation readiness, %	**95**
3	Obtained reactor power, % of full power	**85**
4	Current reactor power, % of full power	**85**
5	Current electric output, MW	**735**
6	Electric generation, million kW-h	**476.821**

Design features

Detailed design of the power unit


Для служебного пользо
Экз.

МИНИСТЕРСТВО СТРОИТЕЛЬСТВА И ЖИЛИЩНО-КОММУНАЛЬНОГО ХОЗЯЙСТВА РОССИЙСКОЙ ФЕДЕРАЦИИ
(МИНСТРОЙ РОССИИ)

ФЕДЕРАЛЬНОЕ АВТОНОМНОЕ УЧРЕЖДЕНИЕ
«ГЛАВНОЕ УПРАВЛЕНИЕ ГОСУДАРСТВЕННОЙ ЭКСПЕРТИЗЫ»
(ФАУ «ГЛАВГОСЭКСПЕРТИЗА РОССИИ»)

УТВЕРЖДАЮ
Заместитель начальника
В.М. Верниг
«26» июня 2015 г.

ПОЛОЖИТЕЛЬНОЕ ЗАКЛЮЧЕНИЕ
ГОСУДАРСТВЕННОЙ ЭКСПЕРТИЗЫ № 897-15/ГГЭ-8609/02

(№ в Реестре 00-1-4-2514-15)

Объект капитального строительства

Белоярская АЭС. Энергоблок № 4
(624250, Свердловская область, г. Заречный,
Белоярская АЭС)

Объект государственной экспертизы

проектная документация и результаты инженерных изысканий
«Белоярская АЭС. Энергоблок № 4»

Проектная документация и результаты инженерных изысканий

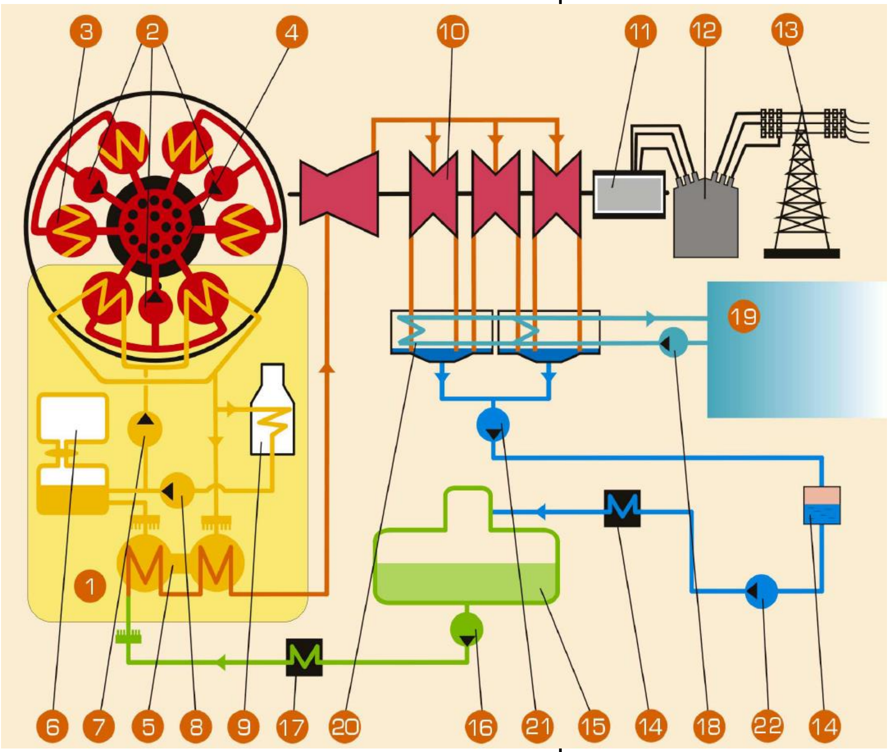
Due to the long duration of the construction project over the period of 1994 to 2011 the reorientation of the requirements for the NPP under construction towards the improvement of their safety and operational reliability happened; the range of the manufactured equipment considerably changed; the regulatory framework was updated. Therefore in 2011 the “Rosatom” State Corporation made decision No. BELAES-2-81R(4,6)2011 about the design correction.

In 2012 to 2014 “Atomproekt” JSC, the General Architect, corrected the BN800 detailed design.

The corrected BN800 detailed design underwent verification in the “Glavgosexpertiza” Federal autonomous institution and obtained State Expert Appraisal Board’s positive opinion No. 97-15/GGE-8909/02 of June 26, 2015.

Design features

Three-circuit heat removal system	As compared with the PWR design the sodium-cooled fast-neutron reactor facility incorporates an intermediate sodium circuit, which leads to larger metal consumption and broader range of installation and adjustment activities.



1. Circulation loop components
2. Primary sodium pump
3. Intermediate heat exchanger
4. Fuel subassemblies
5. Steam generator
6. Expansion tank and water-sodium reaction product dump tank
7. Secondary sodium pump
8. Pump of the emergency shutdown cooling system
9. Sodium-to-air heat exchanger of the emergency shutdown cooling system
10. K-800-130/3000 turbine
11. Alternator
12. Transformer
13. Electric power export to the consumer
14. Low pressure feed heaters
15. Deaerator
16. Feedwater electric pumps
17. High pressure feed heaters
18. Cooling water pump
19. Water reservoir
20. Condenser
21. The first lift condensate pumps
22. The second lift condensate pumps

The existence of the intermediate sodium circuit and emergency shutdown cooling system allows criticality to be obtained without availability of the water-steam circuit systems.

Process features

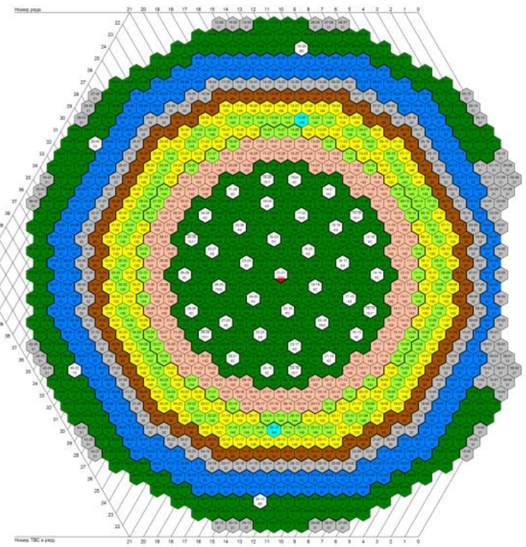
<u>Sodium coolant</u> **Sodium reception facility**	1. In view of the time duration of the sodium accumulation for the reactor filling the sodium reception begins long before the end of installation activities on the main equipment of the unit, that is the initiated operation of some equipment of the unit combines with ongoing installation and construction activities on the rest of the equipment of the unit. The need arises to segregate the start-up facility, which necessitates the immediate issue of the required working documentation, taking the organizational and technical actions to combine operational activities with installation and construction activities, urgent logistic support, operating personnel training and so on. The designer of the sodium reception facility provided for the following: • the possibility to control the equipment from the local panels, • the standalone ventilation systems, • the standalone emergency exhaust ventilation systems.

Process features

Sodium coolant	2. The following additional process systems are needed if sodium is used as a coolant to take into account its peculiarities:
Additional process systems	✓ the sodium purification systems, the cleaning-of-sodium systems, the trace heating systems and the gas (argon) systems, ✓ the gaseous heating system. It is used to heat the reactor vessel before filling it with sodium. The presence of the provisional pipelines of large diameters leads to the extension of the availability time of separate process systems because they cannot be installed, ✓ the trace heating system. The large scope of the heated equipment and pipelines assumes an abrupt increase in the scope of installation of cabling and wiring products. The ventilation systems grow in number, which is accounted for by ensuring the normal temperature conditions in the sodium areas and by the requirements of the fire safety arrangements. Besides some ventilation systems are a part of the sodium reception facility while the civil engineering part for them (upper elevations of the main building) is not ready yet. Thus the need arises to break up large ventilation systems, which necessitates larger scopes and a longer time of installation and construction activities.

Process features

<u>Core refuelling system</u>



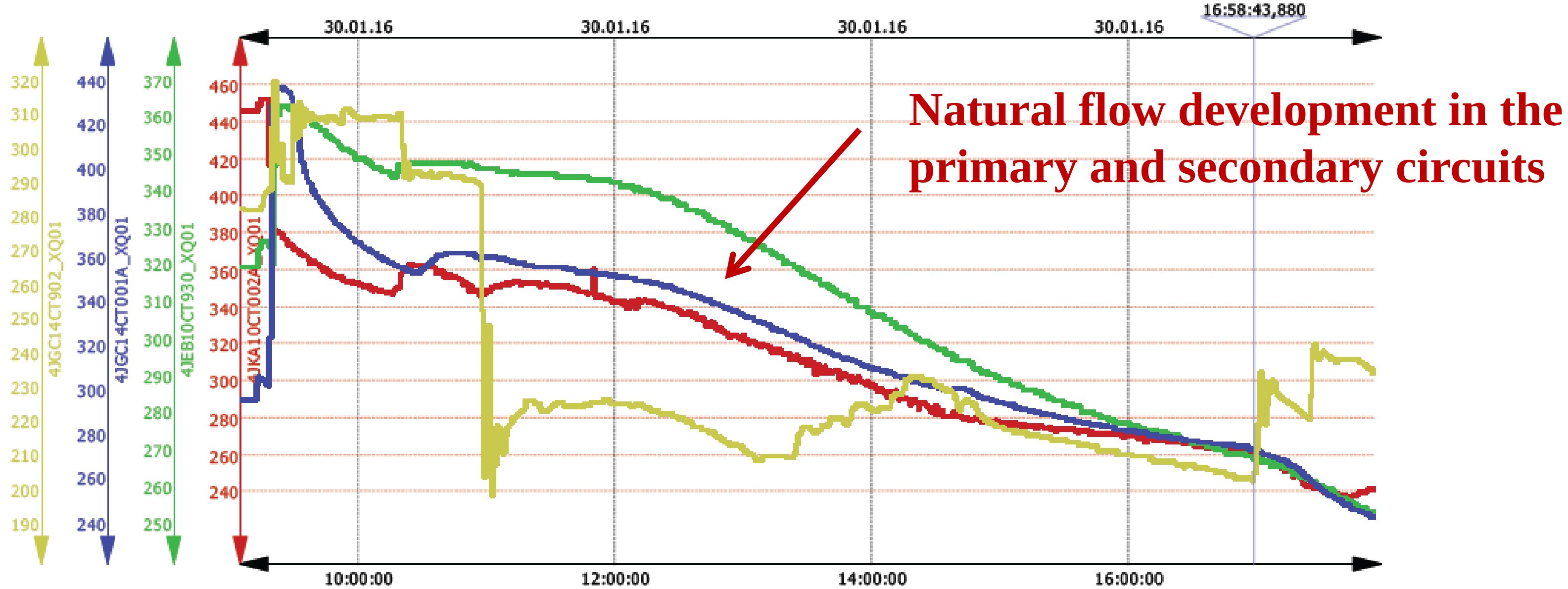
1. The difficulties of the core refuelling system commissioning are accounted for by the refuelling technology, that is under sodium, which makes the visual monitoring of the operation of the refuelling mechanisms impossible.

In order to adjust the refuelling system the preliminary total system adjustment on the bench followed by the adjustment in the reactor vessel before filling it with sodium on the dummy core and the skilled specialists are needed.
There are 1233 core fuel locations (two empty locations are used to reload guide tubes). The core components (fuel subassemblies, control rods, guide tubes) total 1261.

2. In view of the need to harmonize the operation of the in-vessel and ex-vessel handling equipment the combining of the ‘clean’ activities in the reactor with installation and construction activities in the reactor hall is inevitable.

Process features.
Natural flow

The well-developed natural flow in the primary and secondary circuits was confirmed by the tests conducted at the “First connection to grid” stage.

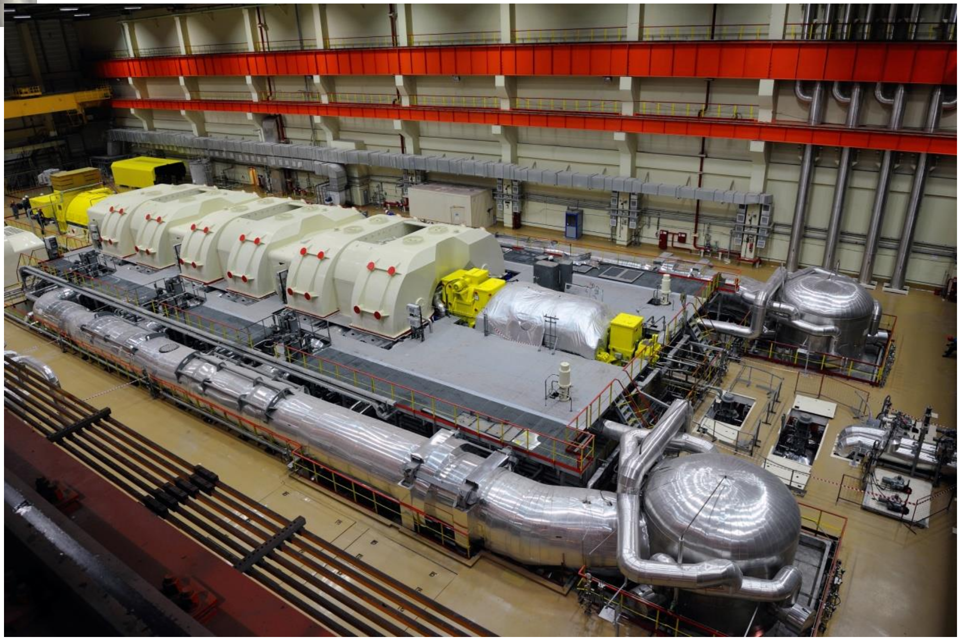


	Сигнал	Описание	Ед изм	Миниму	Максиму	Курсор
(red)	4JKA10CT002A_XQ01	T NA ВЫХ РЕАКТ 0-650 ГРАД	°C	223.512	463.512	262
(green)	4JEB10CT930_XQ01	T NA БАЙП НАП ГЦН 0-650 ГРАД	°C	250	370	267
(blue)	4JGC14CT001A_XQ01	T NA НА ВХ ВТО 0-650 ГРАД	°C	240	440	273
(yellow)	4JGC14CT902_XQ01	T NA НА ВЫХ ВТО 0-650 ГРАД	°C	190	320	202

09:18 – reactor scram with the emergency shutdown cooling system
10:15 – trip of the primary sodium pumps
11:00 – trip of the electromagnetic pumps of the emergency shutdown cooling system
17:00 – restart of electromagnetic pumps of the emergency shutdown cooling system

2015. Reactor hall. Reactor

2015. Turbine hall



2015. Diesel generator set

Thank you for attention!

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