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New Generation VVER-1200 Pilot Unit Specific Commissioning Features

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Introduction

VVER-1200 (V-392M reactor plant): evolutionary design of large-power NPP

NPP-92 design

Design experience of Kudankulam NPP in India

Operating experience of V-320 power units

Recommendations of IAEA missions, EUR requirements

Use of VVER-related R&D with implementation of the evolutionary continuity principle

NPP-2006 design

Innovations of NPP-2006 design

- Improved-safety VVER-1200 reactor plant with reactor pressure vessel and steam generator service life of 60 years
- Set of safety systems using active and passive systems/elements as well as means for severe beyond-design basis accident management
- State-of-the-art radioactive waste management technologies
- Cooling towers assure closed-cycle technological process cooling to minimize environmental impact

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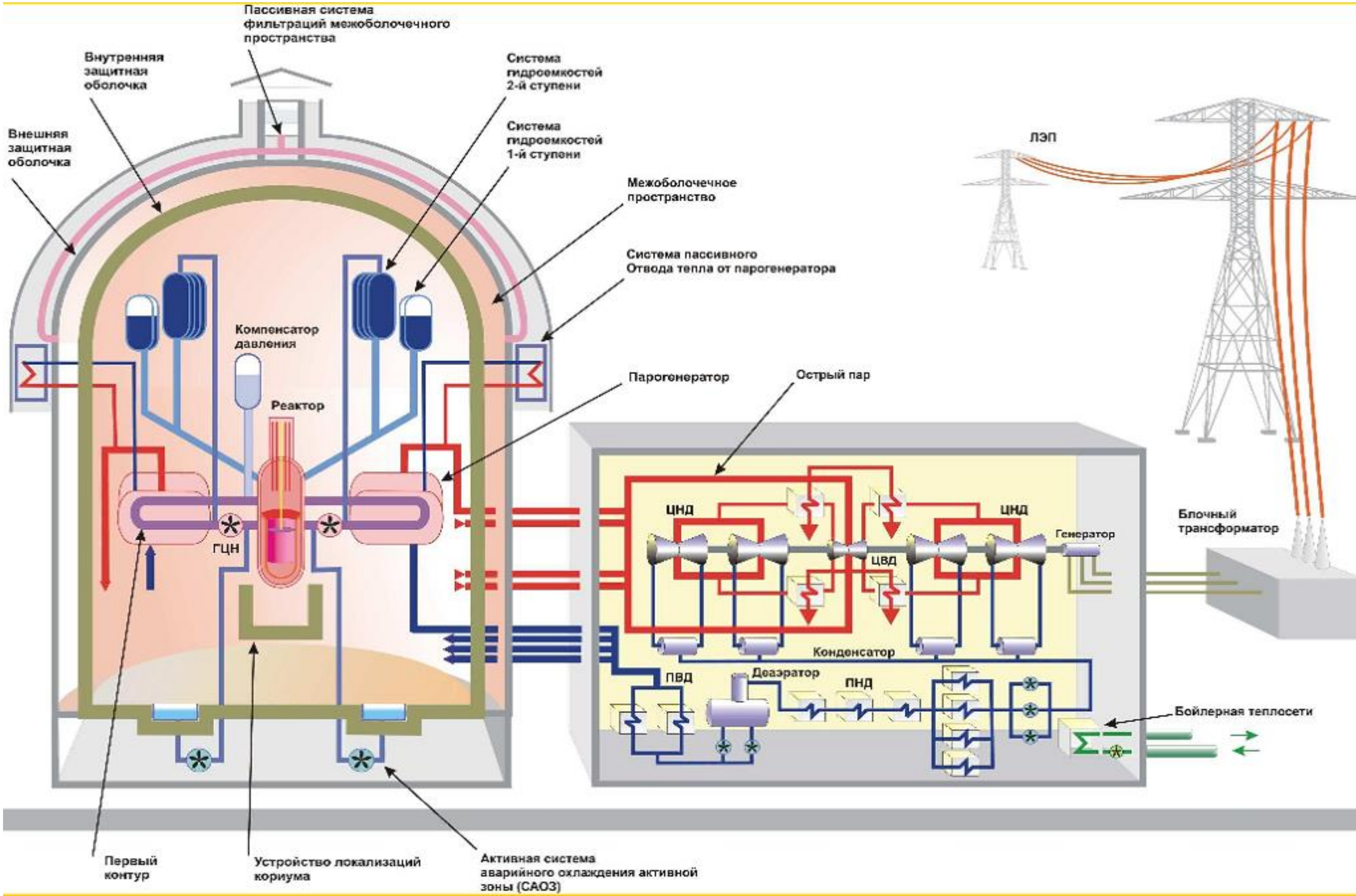
Brief Power Unit Characteristic

Schematic Diagram of NV NPP-2 Power Unit



Safety Assurance Principles

Brief Power Unit Characteristic

Main Parameters

Rated electric power, MW	1198
Rated thermal power, MW	3200
Rated primary circuit pressure, MPa	16,2
Rated steam generator pressure, MPa	6,9
Number of fuel assemblies	163
Maximum enrichment	4,95
Core damage frequency	$2x10^{-7}$
Maximum credible earthquake **Design-basis earthquake,** point	7 6

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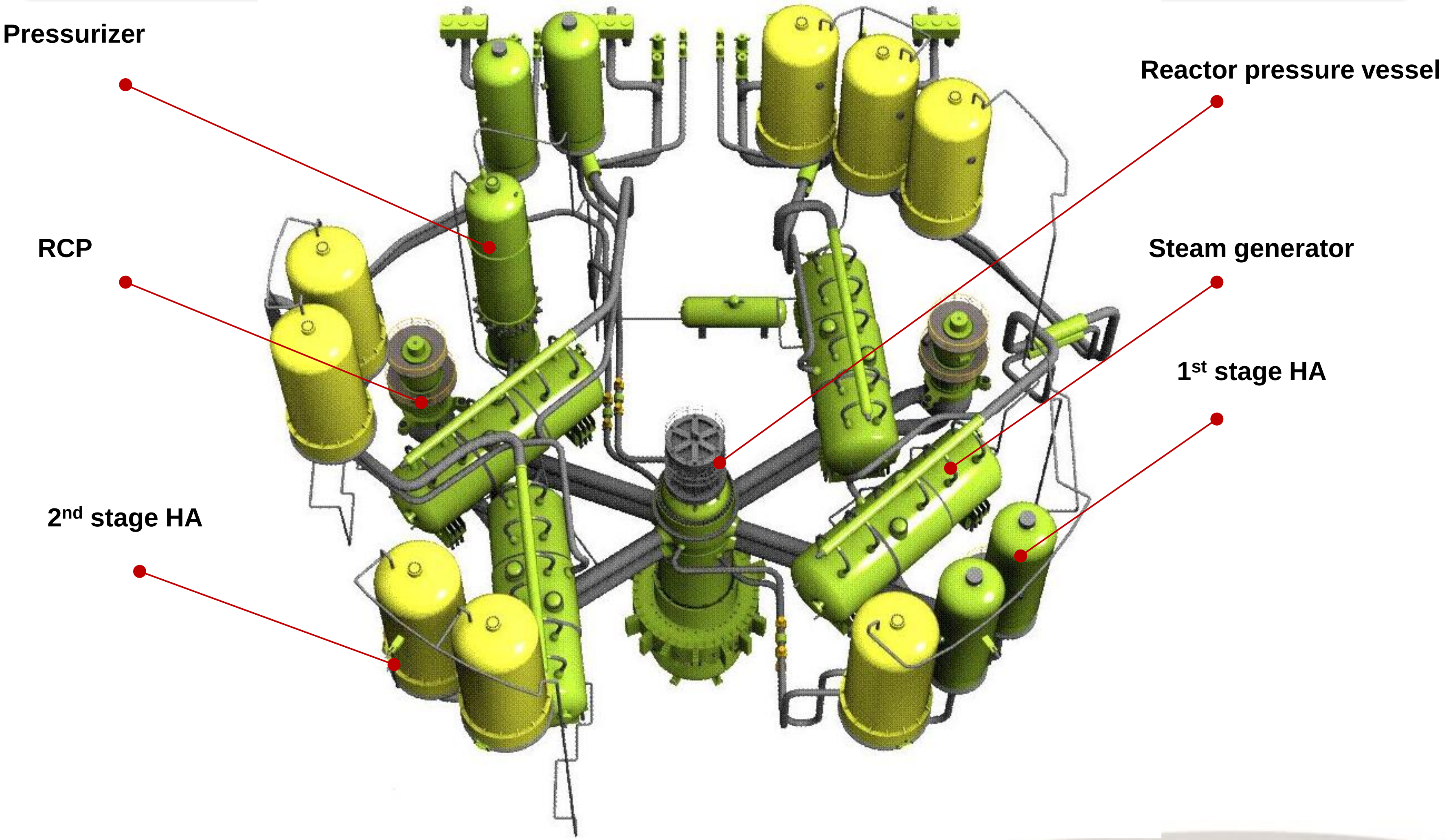
Nuclear Island
Reactor plant



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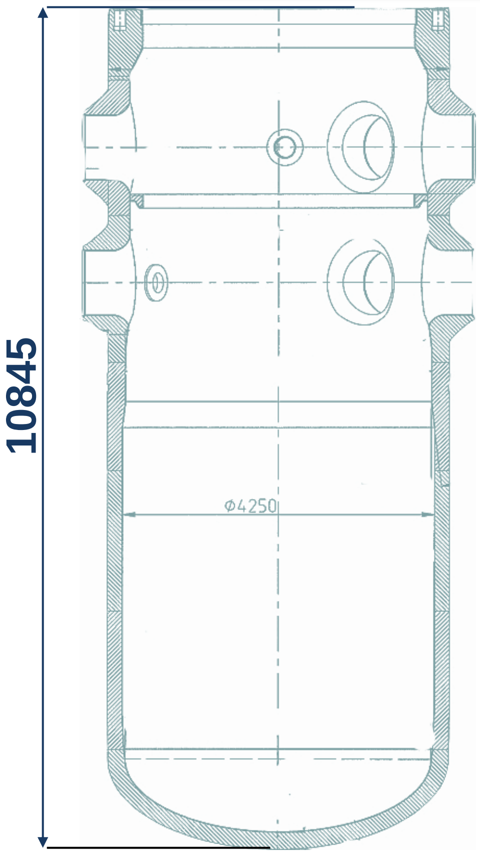
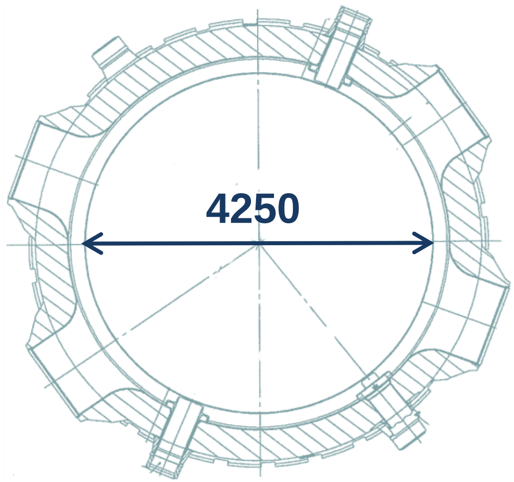
Reactor Plant and Primary Circuit Components
Main characteristics

Power, MW	1195,4
Thermal power, MW	3200
Core pressure, MPa	16,2 MPa
Flow rate across the core, (m^3/h)	88000
Coolant temperature at core inlet/outlet, (°C)	298,2/328,6
RCP	4 Q=22000 m^3/h H=0.59 MPa
Steam generator	4 (horizontal) Pnom.=6.9 MPa Gnom.=1600 t/h
Hydro-accumulators Passive core flooding	1st stage HAs 4 * 50 m^3, P=5.9 MPa 2nd stage HAs 8 * 120 m^3, P=0.1 MPa

Reactor Plant and Primary Circuit Components
Reactor Pressure Vessel

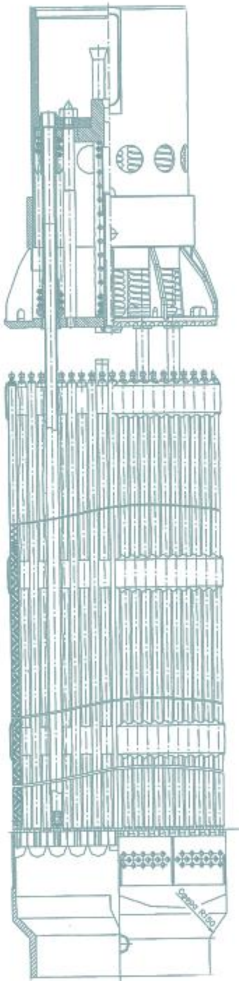




Reactor pressure vessel (RPV) differences from standard reactor plant RPV

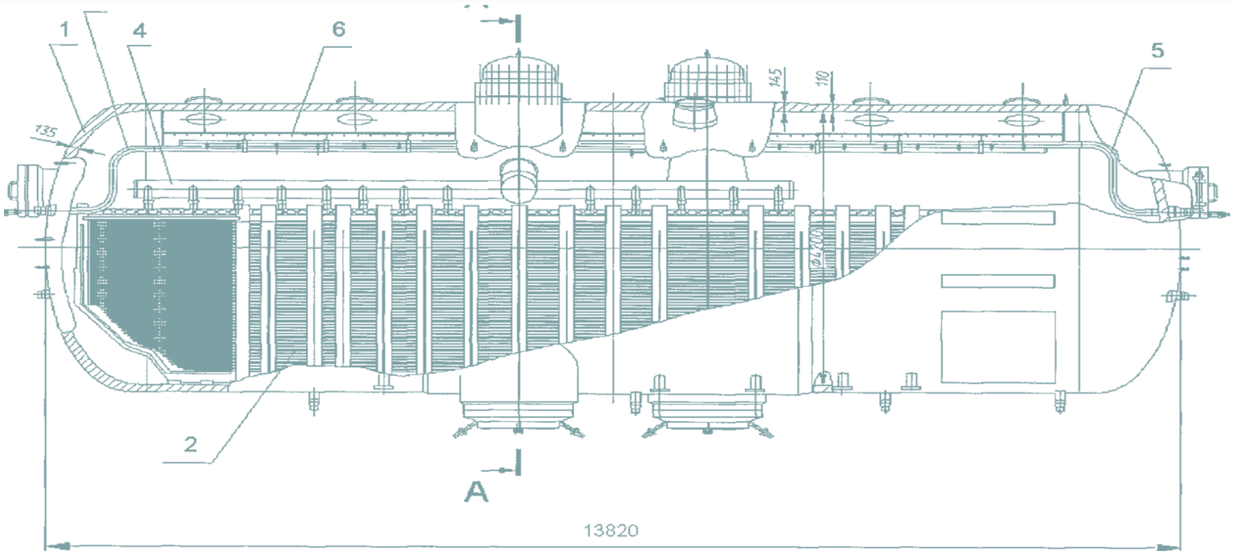
- diameter increased by 100 mm;
- length increased by 300 mm;
- limited nickel content in base and weld metal;
- location of surveillance specimens directly on reactor pressure vessel wall

Reactor Plant and Primary Circuit Components
Core



Type	TVS-2006
Fuel assembly type	Hexagonal prism
Number of fuel assemblies	163(312: uranium fuel elements + gadolinium fuel elements)
Maximum enrichment	4,95
Active fuel length (m)	3,73
Number of control rods	121 (12 groups)
Burnup (MW*day/kg U)	55,5
Fuel cycle (month)	from 36 to 48
Average linear power density (W/cm)	187,3

Reactor Plant and Primary Circuit Components
Steam Generator



Name of parameter	Value
Steaming capacity, t/h	**1602**
Generated steam pressure at steam header outlet, MPa	**7,00±0,10**
Generated steam temperature at SG steam header outlet, °C	**285,8±1,0**
Feedwater temperature, °C	**225±5**
Steam humidity at SG steam header outlet, %, not more than	**0,20**
Maximum blowdown flowrate from salt compartment, t/h	**up to 40**
Maximum total blowdown flowrate of all SGs with switched-on periodic blowdown of one SG, t/h	**140**

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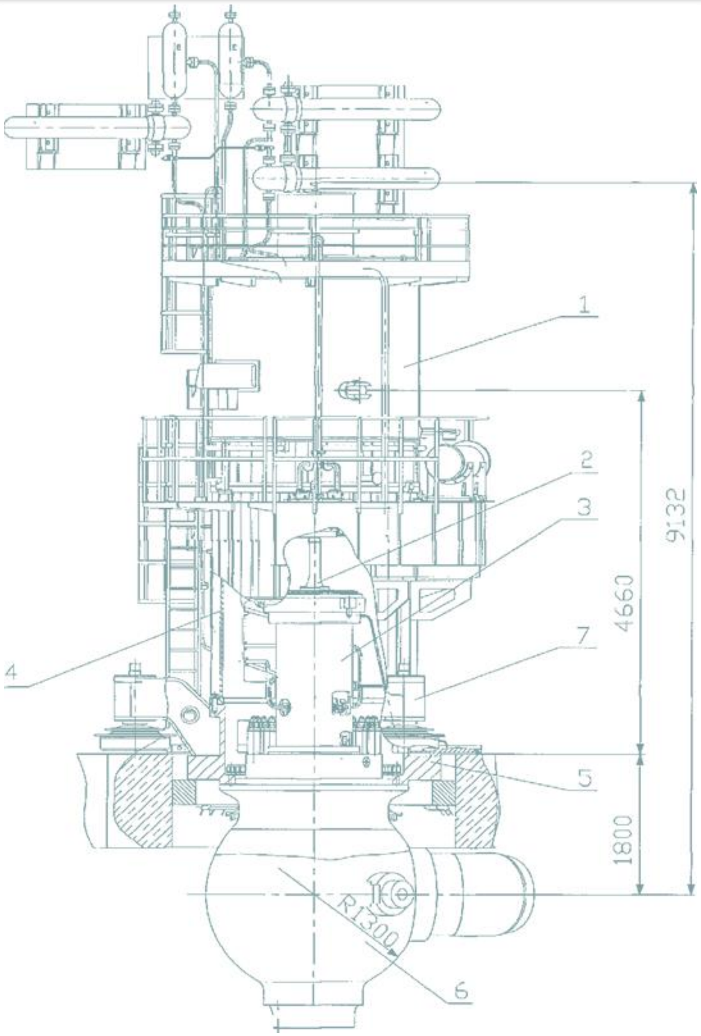
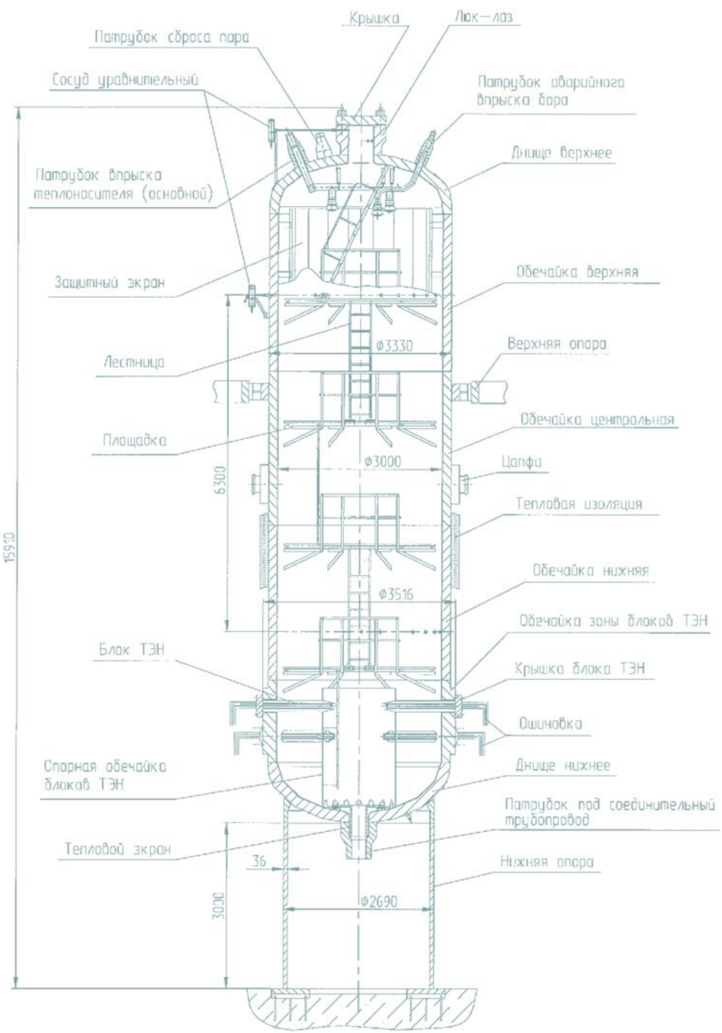
Reactor Plant and Primary Circuit Components
Reactor Coolant Pump



Name of parameter	Value
Pump capacity, m^3/h	**22600**
Pump head, MPa	**0,610+0,025**
Coolant temperature, °C	**$298{,}2^{+2}_{-4}$**
Rated suction pressure, MPa	**16,02**
Design temperature, °C	**350**
Design excessive pressure, MPa	**17,64**
(Synchronous) speed of rotation, rev./min.	**1000/750**
Power consumed by RCP-1391 in hot mode, kW, not more than	**5000**
Maximum power consumed by RCP-1391 in cold state, kW, not more than	**6800**
Rated feed current voltage, V	**6000**
Feed current frequency, Hz	**50**

Reactor Plant and Primary Circuit Components
Pressurizer



Name of parameter	Value
Rated steady-state mode (absolute) pressure, MPa	**16,1+0,3**
Design pressure, MPa	**17,64**
Pressurizer coolant temperature under rated steady-state mode,ºC	**347,9**
Design temperature, ºC	**350**
Coolant level under rated mode, mm	**8170±150**
Total pressurizer volume, m	**79**
Coolant volume under rated steady-state mode, m	**55**
Coolant volume at reactor plant zero power (corresponding to pressurizer coolant level of 5,1 m), m^3	**38,7**

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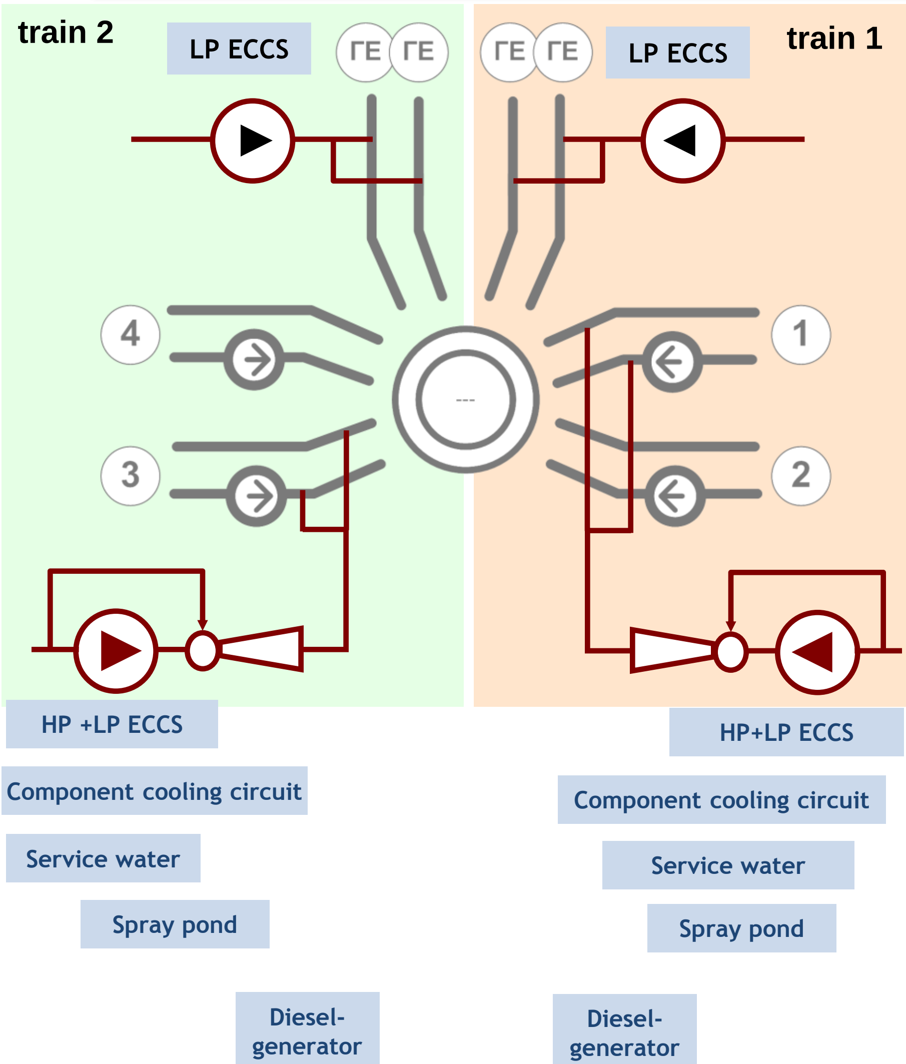
Composition of active and passive safety systems

- 2 emergency power supply trains
- 2 trains of low pressure ECCS with 2 ECCS heat exchangers
- 2 trains of high pressure ECCS with an ejector
- 2 boron injection trains
- 2 spray system trains (perform the function of spent fuel pool cooling in normal operation modes)
- 2 trains of SG emergency cooldown (with low-pressure pumps and closed-circuit operation for unlimited time)
- 2 trains of support systems for heat removal to ultimate heat sink, including 2 spray ponds
- 2 control system trains

- 4 groups of 2nd stage hydro-accumulators
- 4 trains of SG passive heat removal system
- System for melted core confinement and cooling
- System for removal of non-organized gas leakages from inter-containment space

ECCS and Support Systems (1JNA)

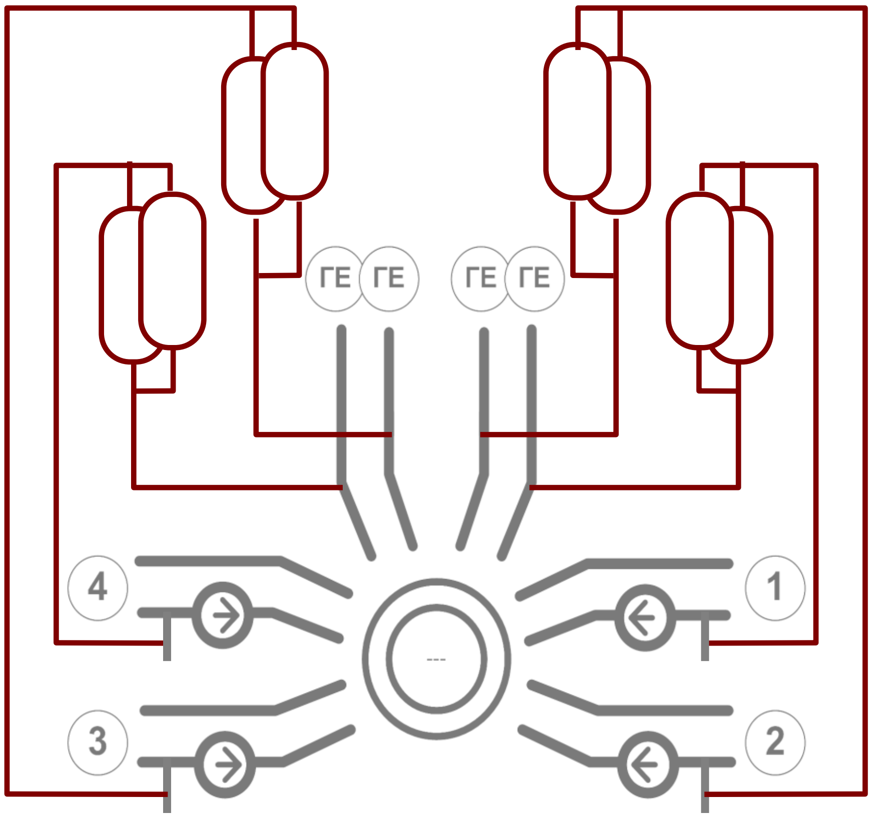


System for primary circuit emergency and planned cooldown and spent fuel pool cooling is intended for:

- reactor plant cooldown under all modes of unit operation;
- residual heat removal from reactor fuel to component cooling circuit;
- residual spent fuel pool heat removal under all modes of unit operation;
- chemicals injection into primary circuit to fix radioactive iodine in case of accidents involving primary circuit leaks;
- maintaining reactor coolant inventory in case of ‘large leak’ and emergency make-up during ‘small leaks’;
- emergency core cooldown and subsequent long-term residual heat removal in case of accidents related to primary circuit depressurization, including ND850 total cross-section pipeline rupture;
- performing the function of spray pumps under beyond-design-basis accident.

It has a double-train structure

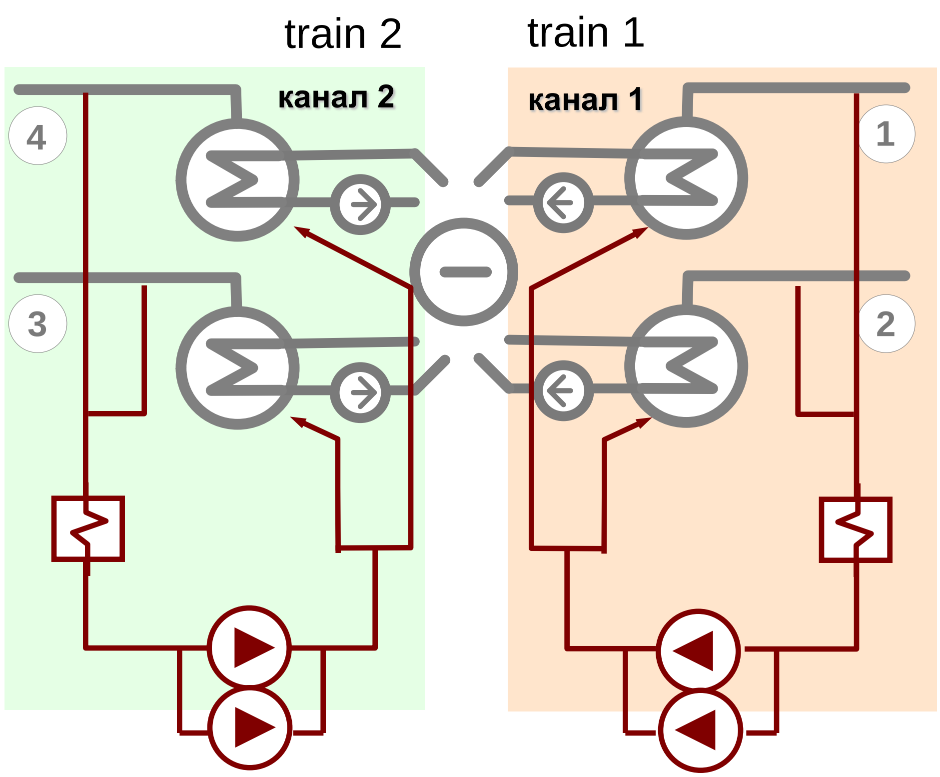
Second-stage hydro-accumulator system (1JNG10-40)



Second-stage hydro-accumulators of the passive core flooding system are intended for:

- passive supply of boron solution with concentration of 16 g/dm^3 for core flooding in case of loss-of-coolant accidents when the coolant level is low and the primary circuit pressure drops below 1,5 MPa.
- boron solution storage to fill refueling pool compartments at the unit shutdown for refueling outage.

System for emergency heat removal through SGs (1JNB10-40)



System for SG emergency cooldown is meant for:

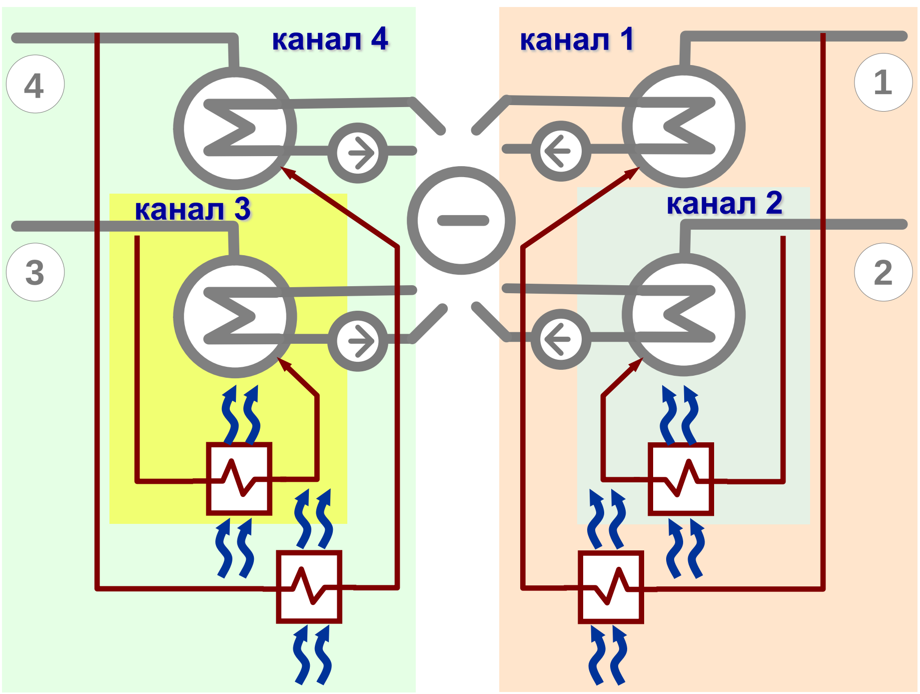
- reactor core residual heat removal and reactor plant cooldown in emergency situations related to loss of power supply or normal heat removal through secondary circuit, including SG steam and feedwater pipeline leaks;
- reactor core residual heat removal and reactor plant cooldown in emergency situations related to primary circuit depressurization, including main circulation pipeline break and primary-to-secondary leak.

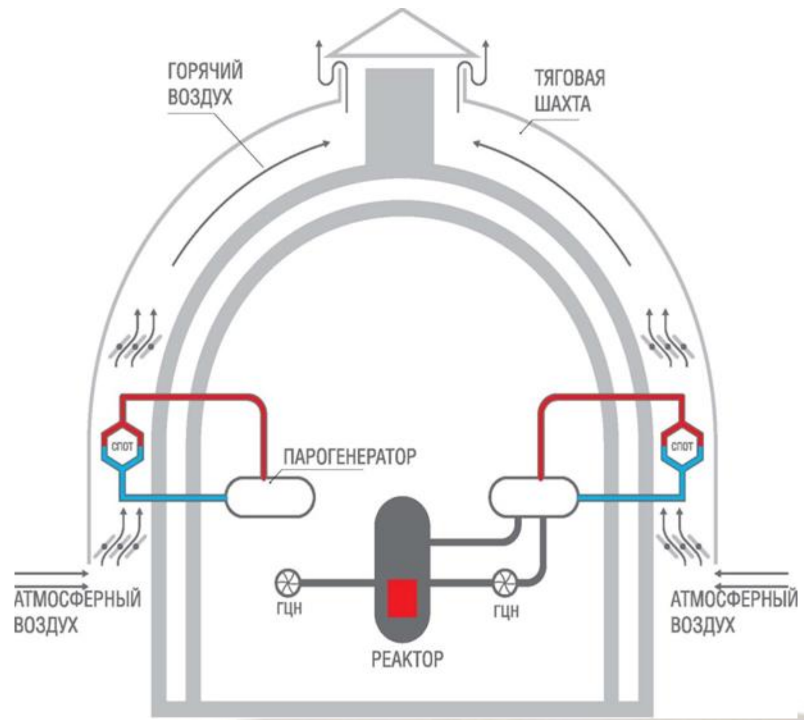
It has a double-train structure

Passive SG heat removal (1JNB50-80)

Passive four-train system with train redundancy of 4 x 33 %, with 2 AIR-cooled heat-exchangers (of 8 MW each) in each train (time of operation is unlimited)

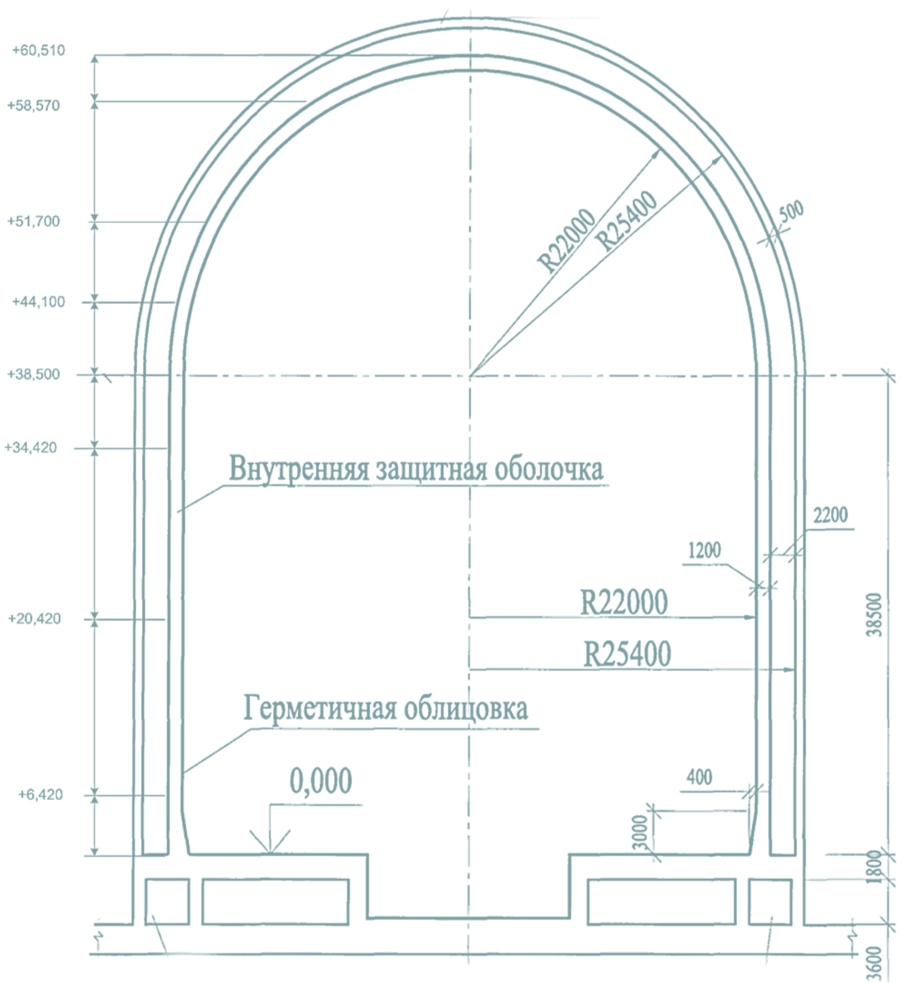
Passive heat removal system is a protective safety system based on the passive principle of operation that assures reactor core residual heat removal via the secondary circuit





Safety Systems

Double-wall containment



Containment diameter (m)
Internal containment wall: 44 External containment wall: 51.8
Maximum excessive pressure (MPa)
0,4

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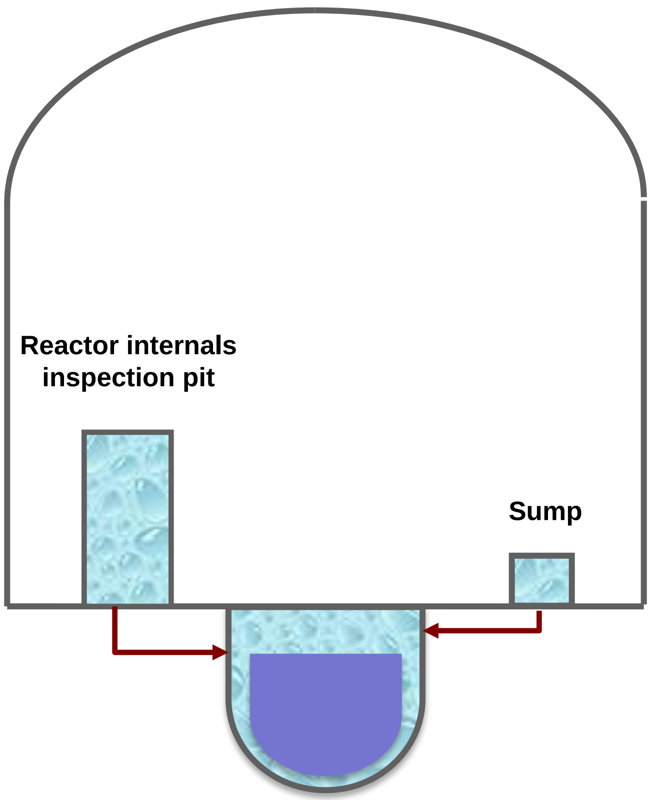
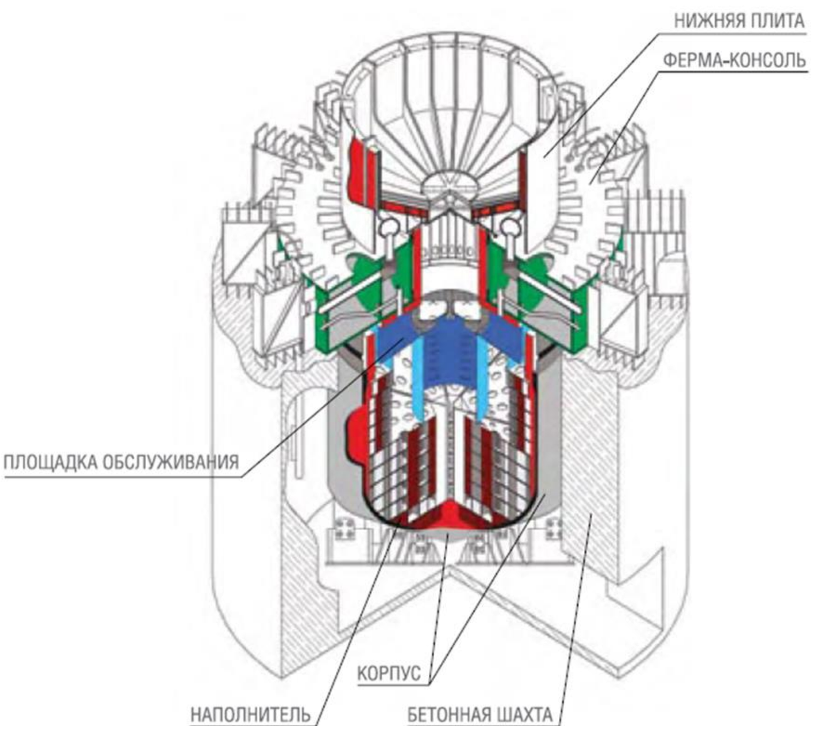
Melted Core Confinement and Cooling System (1JKM)

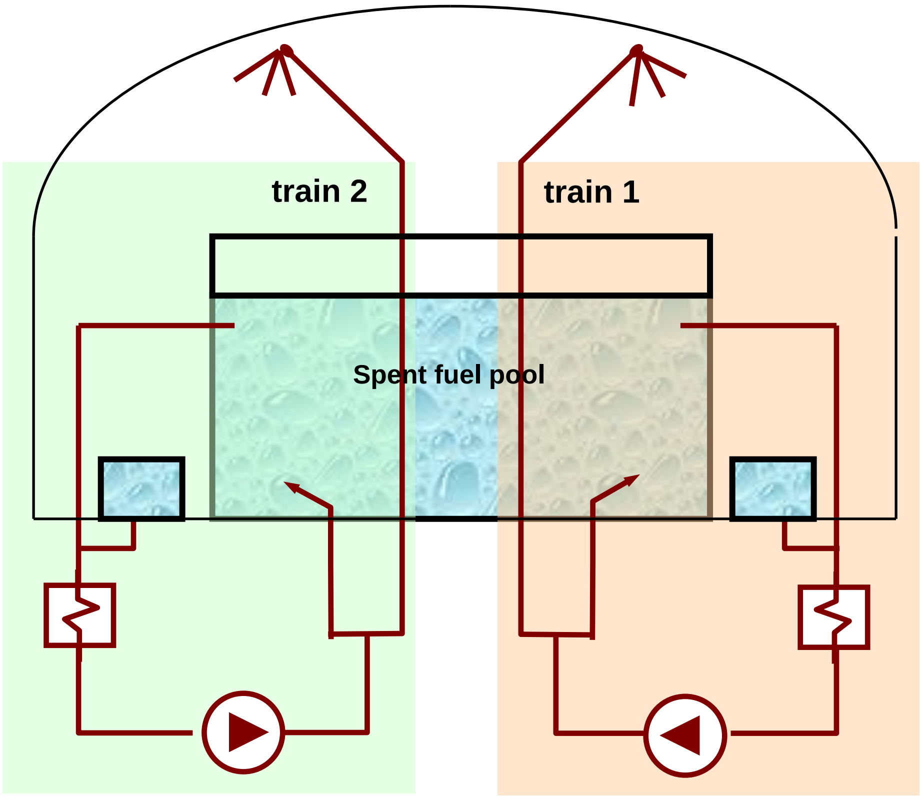




Safety Systems

Spray System (1JMN)

Active double-train system



Spray system is designed to perform the function of parameter (pressure and temperature) reduction inside the containment and the function of radioactive iodine fixation

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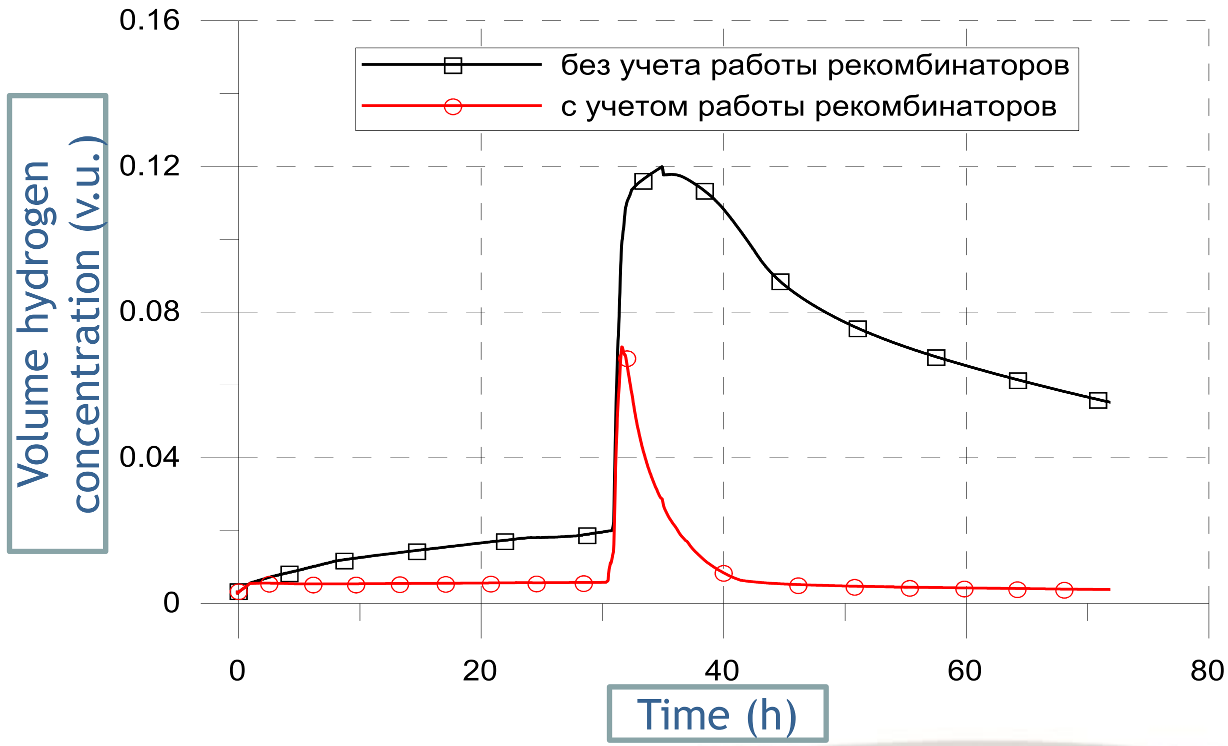
System for emergency containment hydrogen removal (1JMT)

The JMT system assures hydrogen non-explosiveness in the containment. The system uses passive hydrogen recombiners which are installed in the locations of its possible accumulation. Platinum is used as a catalyst.

RVK-1000: 187 pcs.

RVK-500: 12 pcs.



BDBA management.
Additional facilities and systems

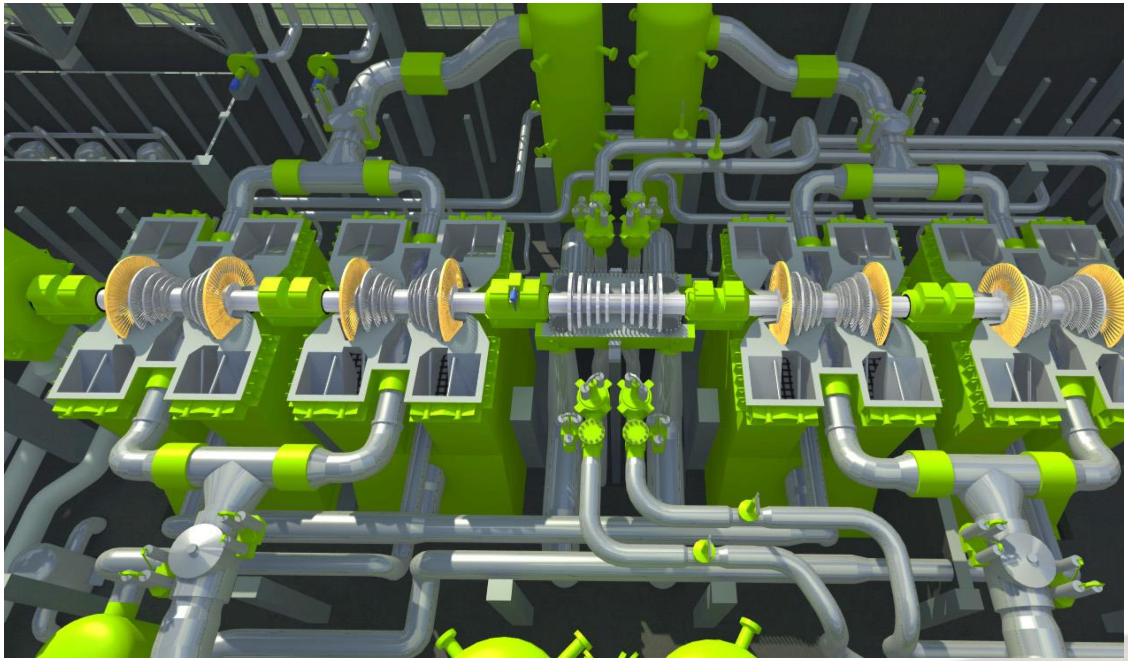
The following additional facilities and systems are integrated in the design:

- Emergency diesel-generator plant;
- Mobile pumping unit;
- Mechanical-draft cooling tower;
- Air-bottle station for MCR/RSP habitability assurance;
- Emergency and post-emergency monitoring system;
- Emergency and post-emergency sampling system;
- Diverse protections system.

Turbo-generator part

Turbine system

Turbine system	К-1200-6,8/50
Turbine system diagram	2LPT+HPT+2LPT
Regenerative heating diagram	4LPH+D+2HPH
Mass steam flowrate (t/h)	6461,5
Steam pressure (MPa)	6,8



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Turbo-generator

TZV-1200-2AUZ: water cooling, power of 1200MW, speed of rotation: 3000 rev./min., six-phase design, two 24 kV three-phase windings are shifted relatively to each other by 30 degrees (50% of rated power each)

Electric Power Supply

Power Delivery Diagram

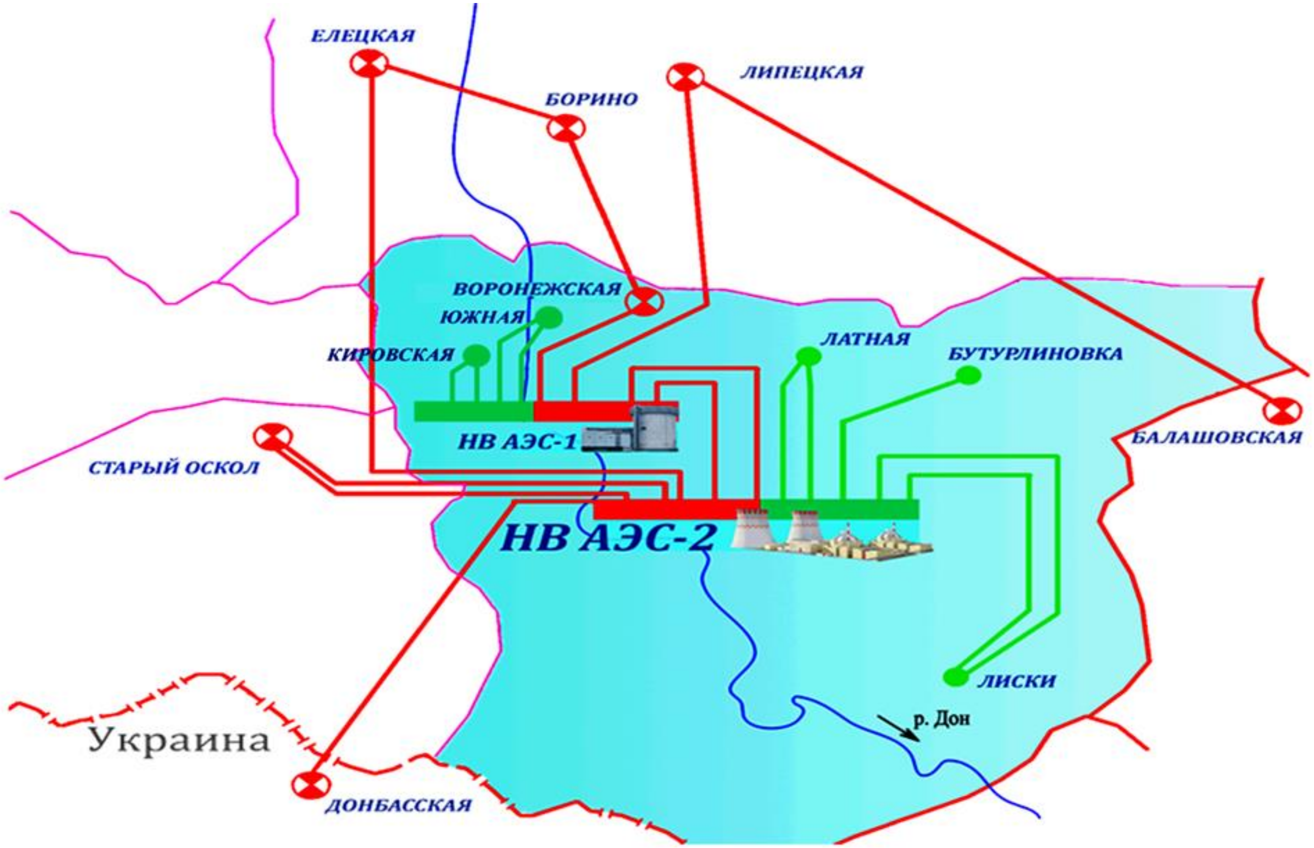

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Diagram of power delivery and unit auxiliaries

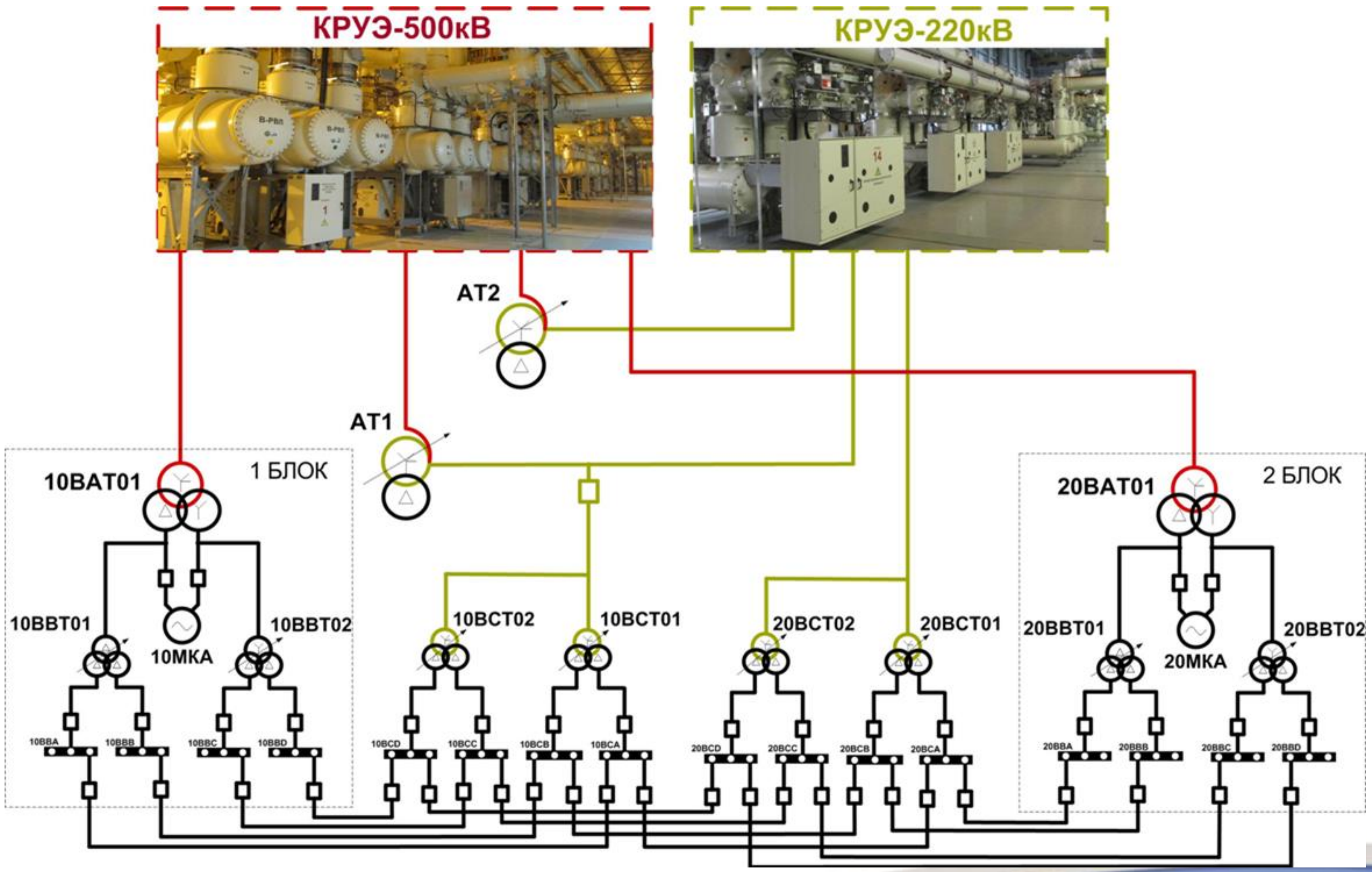
Gas-insulated 220 kV switchgear

Distinctive features of gas-insulated switchgear are as follows:

- *economic efficiency*
- *high operational reliability*
- *reliable insulation*
- *high leak-tightness*
- *long operation*
- *low operating costs*
- *good components access and ergonomics*
- *high degree of availability*
- *reliable operation even in extreme weather conditions*

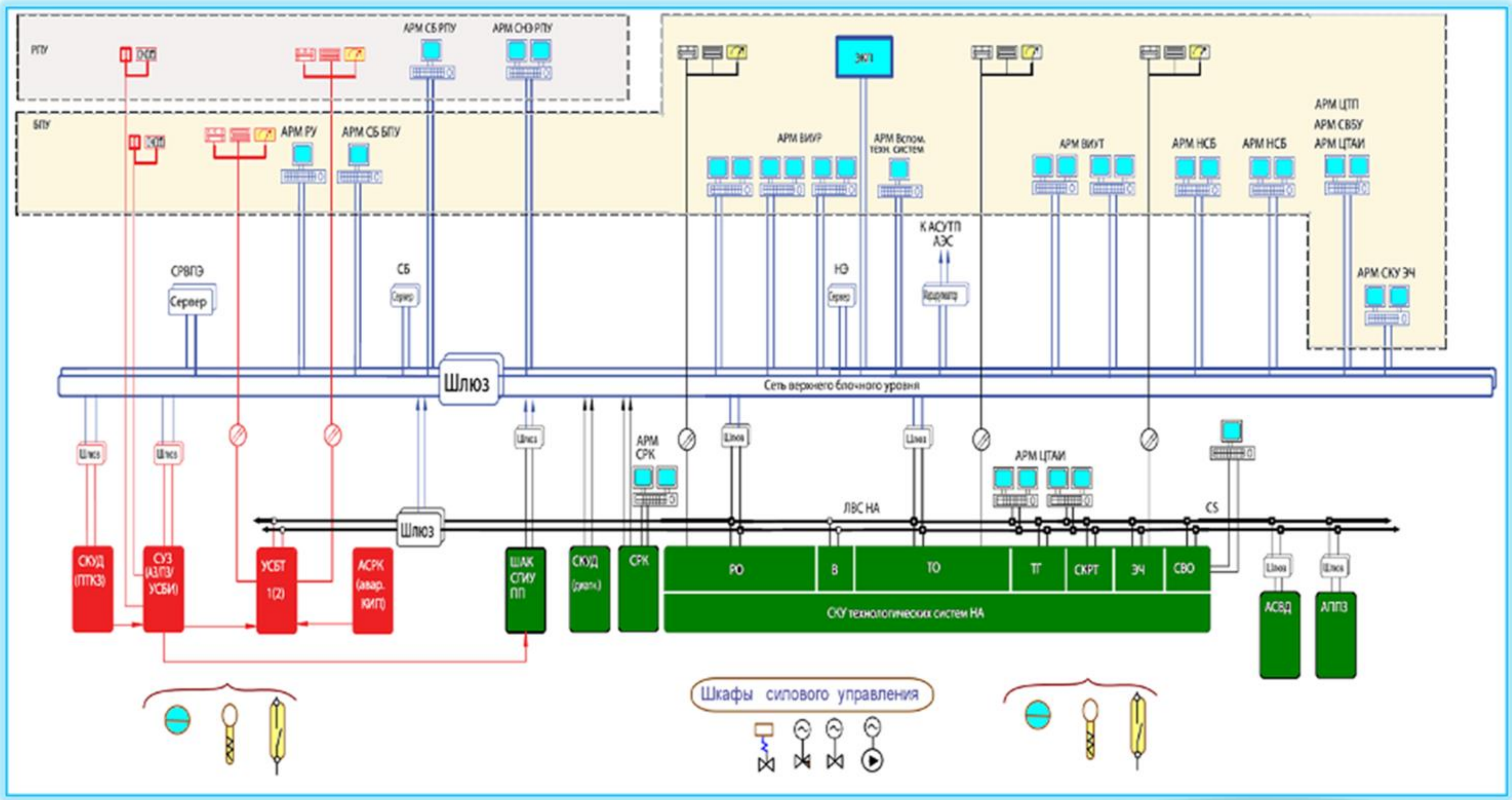
Diagram of power delivery and unit auxiliaries

Facilities circuit diagram



Monitoring and Control

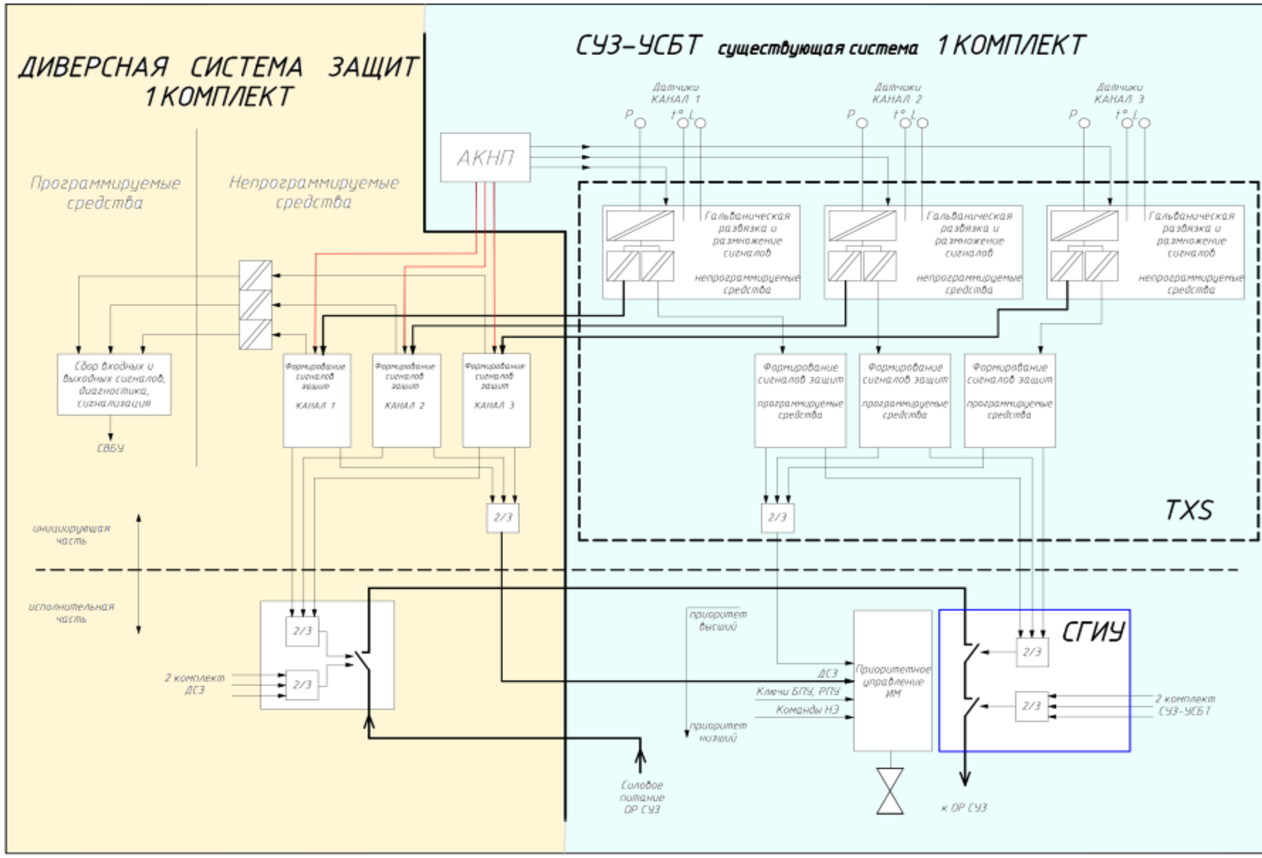
Process control computer system architecture



Sub-system of diverse protections

Overcoming of common mode failures

In order to implement the diversity principle, the design of the process control computer system uses a diverse protections system, based on non-programmable hardware, independent on the emergency protection-control safety system



System for demineralized water preparation and storage

Capacity of the plant:

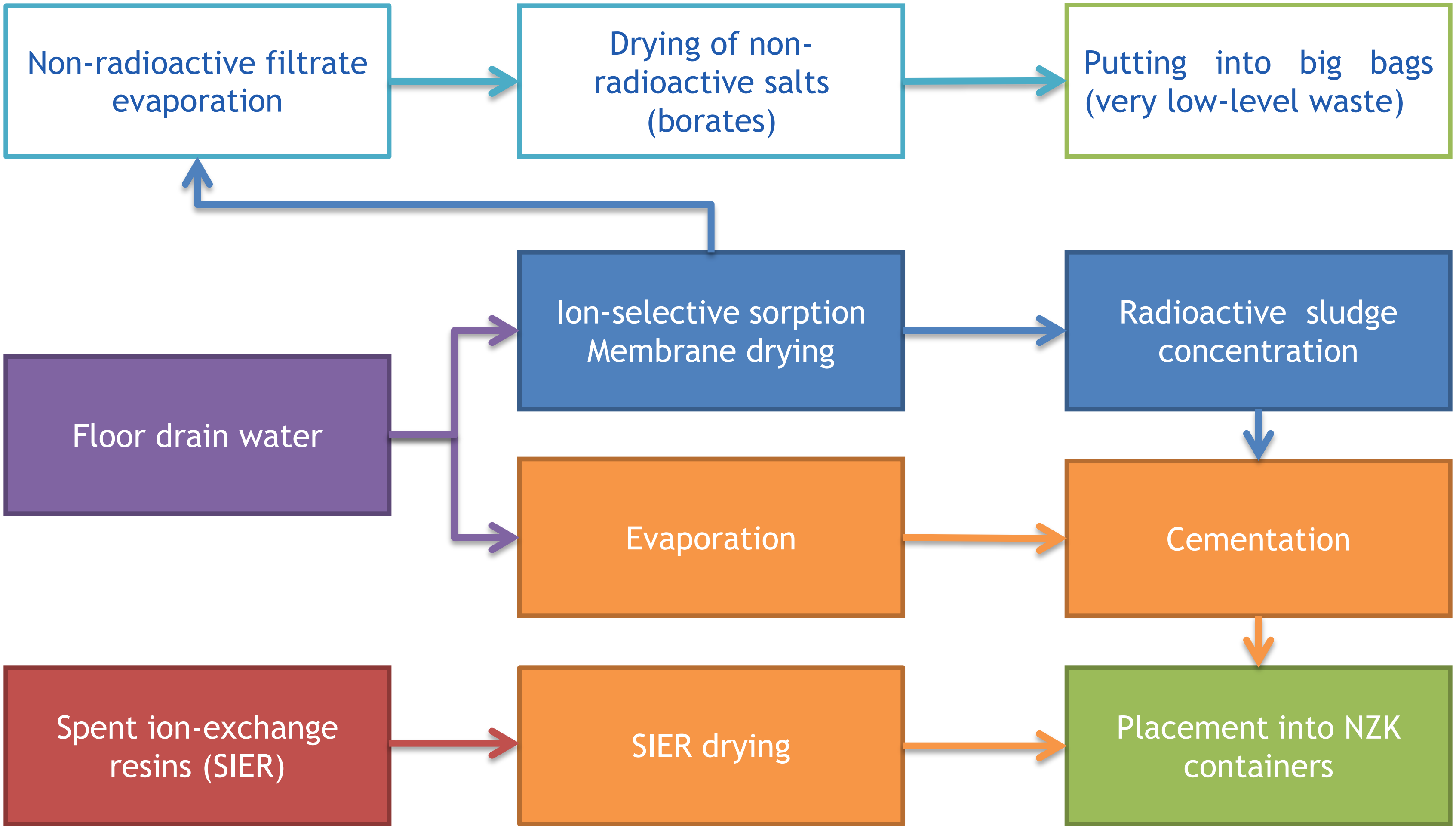
- in terms of partially demineralized water for spray ponds: 90 m^3/h;
- in terms of chemically demineralized water: 165 m^3/h.

Water preparation stages:

- preliminary water purification, using ultrafiltration plants;
- mechanical filtration;
- ultraviolet disinfection plants;
- inverse osmosis plants;
- counterflow ion-exchange filters (APCORE technology);
- deep water demineralization through mixed-bed polishers, with external regeneration.

Radioactive Waste Management

Liquid Radioactive Waste



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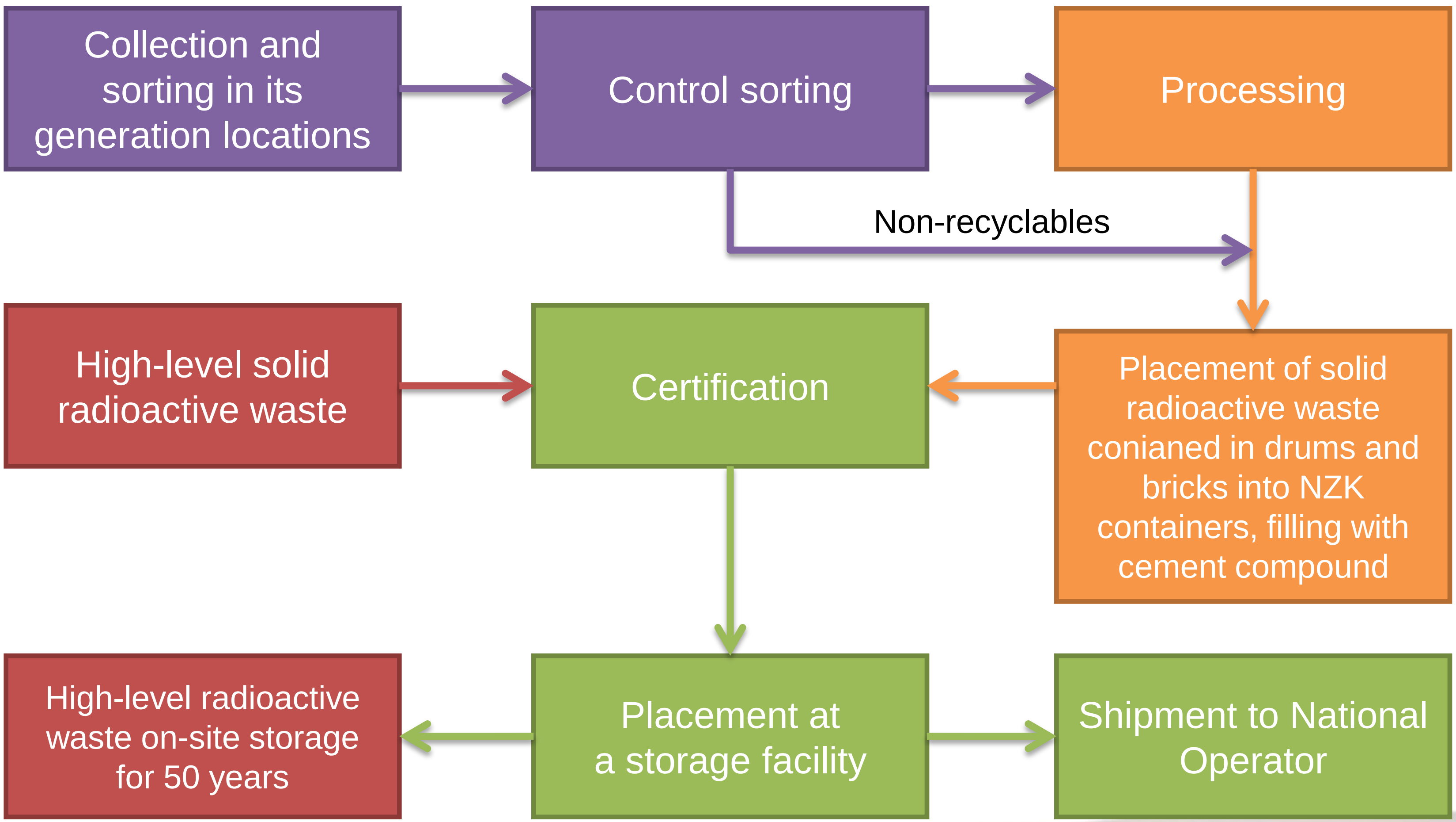
Radioactive Waste Management

Solid Radioactive Waste



Specific Features of Power Unit Commissioning

Comparison of power unit indicators

Number of	VVER-1000 (Rostov Unit 3)	VVER-1200 (NV NPP)
Process systems	247	482
Pumping units	339	779
Ventilation units, ventilation plants	676	1 600
Hoisting mechanisms	35	158
Control rod drives	75	121
Motor-driven valves	4 319	6 175
Algorithms of functional control groups	34	154
Process protections, interlocks and alarms	3 686	11 140
Measuring channels	6 238	12 081
Tests in all commissioning phases	1 638	2 231

Specific Features of Unit Commissioning

Phases and key events in Power Unit 6 commissioning

It. No.	Phases/sub-phases	Start	End	Duration, days
1	**Sub-phase A-0 "Preparatory sub-phase"**	**30.05.2012**	**20.02.2015**	**996**
2	**Sub-phase A-1 "Equipment tests and tryouts"**	**21.02.2015**	**04.09.2015**	**195**
3	**Sub-phase A-3 "Reactor plant cold and hot run"**	**04.09.2015**	**19.12.2015**	**105**
3.1	Phase A-3.1 of sub-phase A-3 "Hydraulic tests and circulation flushing of reactor plant primary circuit"	04.09.2015	06.10.2015	32
3.2	Reactor plant preparation for hot run (inter-phase inspection)	06.10.2015	10.11.2015	35
3.3	Phase A-3.2 of sub-phase A-3 "Reactor plant hot run"	11.11.2015	19.12.2015	38
4	**Sub-phase A-2 "Containment tests"**	**19.12.2015**	**26.12.2015**	**7**
5	**Sub-phase A-4 "Inspection of reactor plant major components"**	**26.12.2015**	**22.03.2016**	**87**
6	**Phase B "Physical start-up"**	**23.03.2016**		
6.1	Phase B-1.1 "Dry loading" of sub-phase B-1 "Reactor loading with nuclear fuel and tests in sub-critical state"	23.03.2016	27.03.2016	4
6.2	Phase B-1.2 "Wet loading and tests in sub-critical state" of sub-phase B-1 "Reactor loading with nuclear fuel and tests in sub-critical phase"	27.03.2016		

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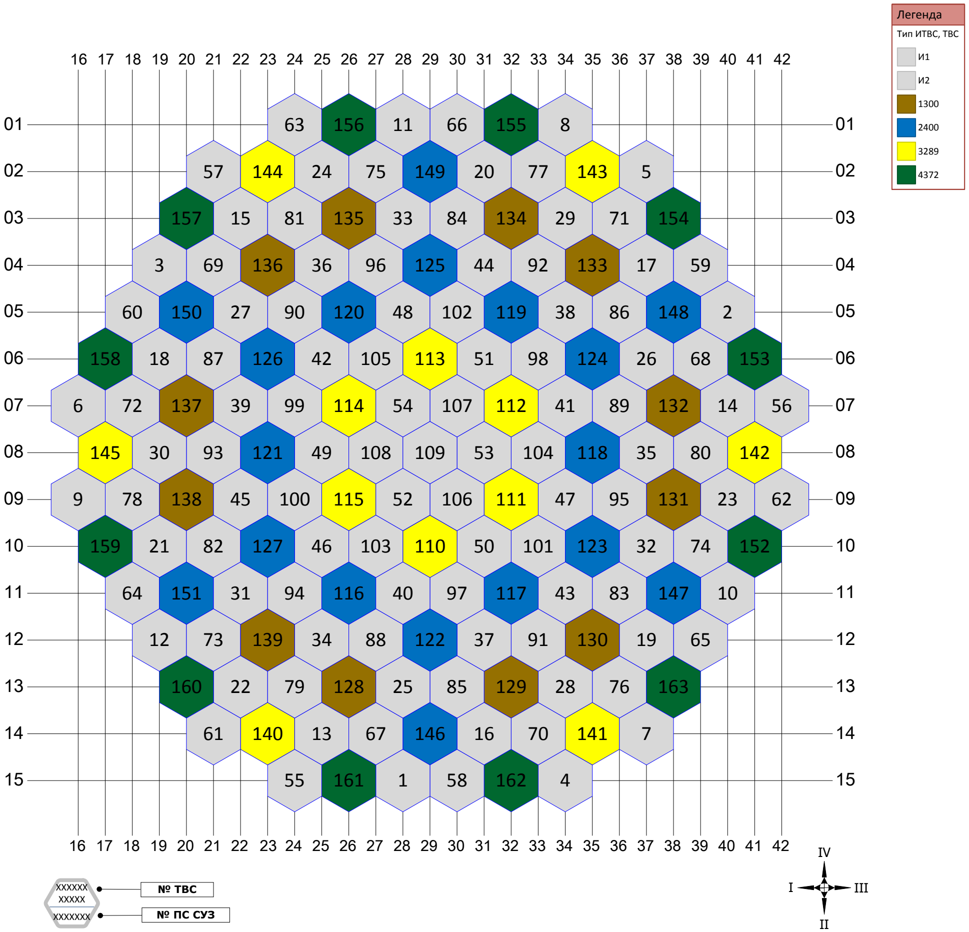
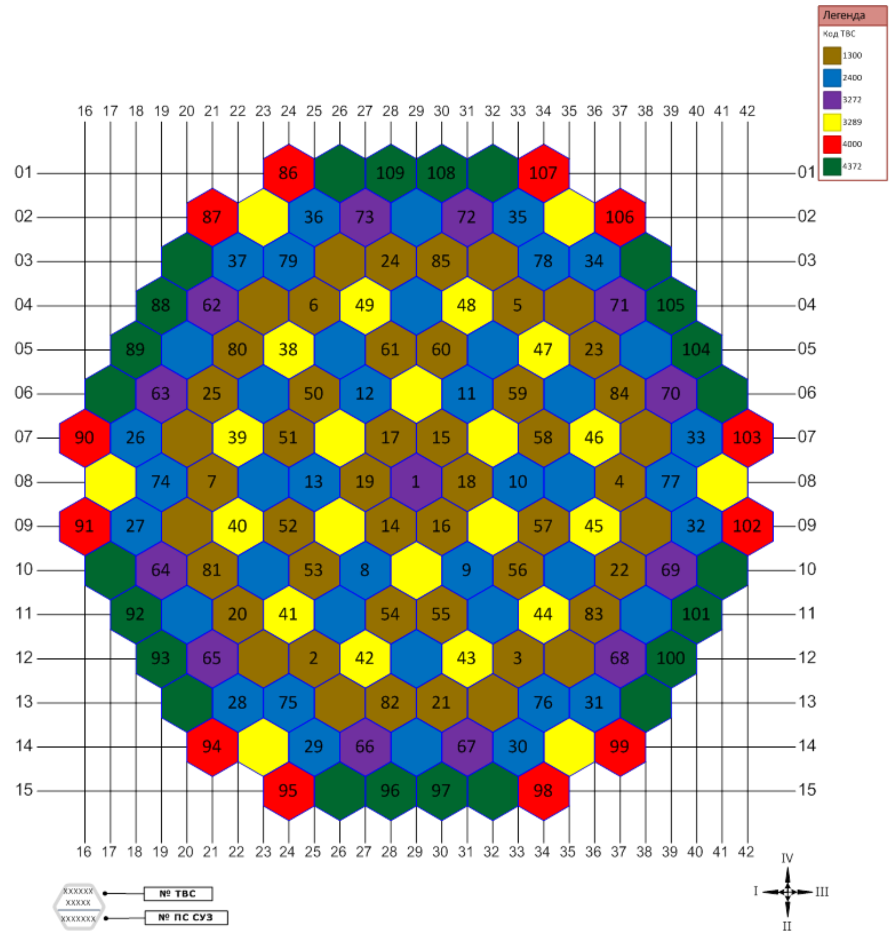
Problems and Specific Features of Commissioning Activities
Improved method for fuel loading into the core



Phase B-1.1



Phase B-1.2

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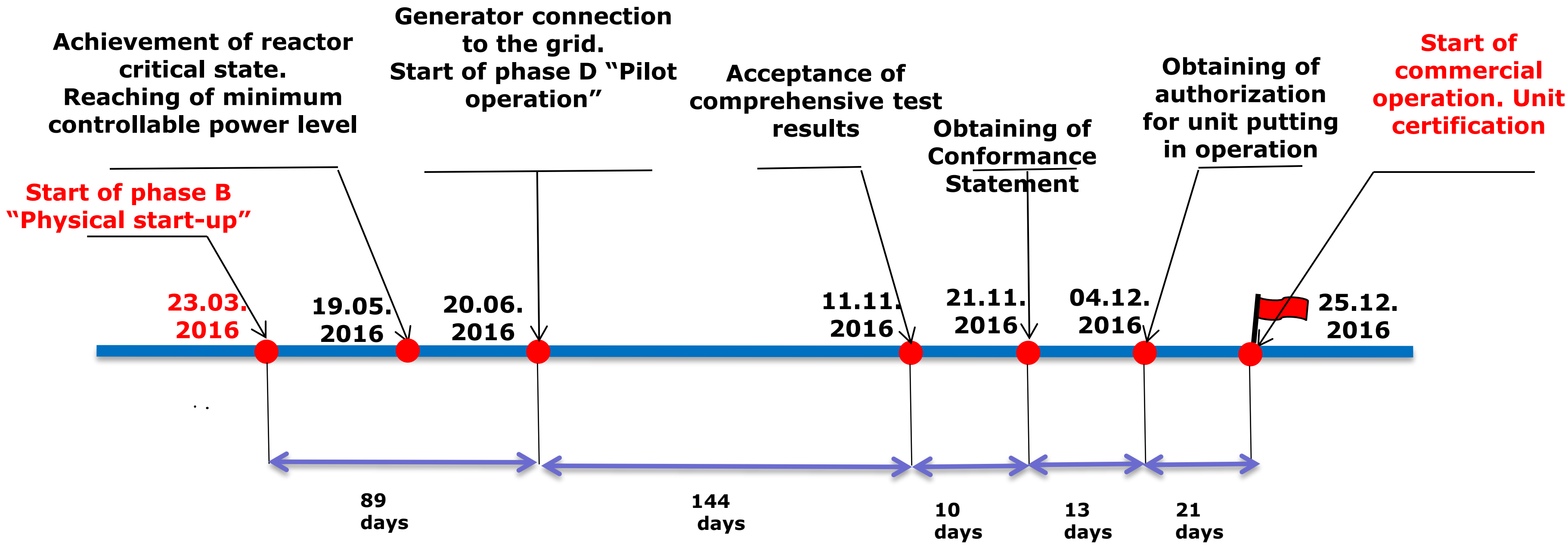
Specific Features of Power Unit 6 Commissioning

Schedule for Power Unit 6 start-up



Conclusion

In implementing the “NPP-2006” project on Novovoronezh NPP-2 site, the following main tasks meeting the state-of-the–art level of nuclear power development have been successfully solved:

Achievement of NPP safety indicators required by current standards;

Account taken of international trends in NPP safety improvement;

Maximum use of technologies and equipment proven by operating experience.

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Thank You for Your Attention!