ATOMENERGOPROEKT

State Corporation "Rosatom" Enterprise

ADDITIONAL INFORMATION ON MODERN VVER GEN III TECHNOLOGY

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Introduction

The main intention of this presentation is to provide:

- - some clarifications regarding the structure and composition of safety systems of modern VVER Gen III NPPs
- - information on the improvements implemented in the latest designs based on AES-92 design

Basing on the same Technical assignment for AES-2006 NPP two different NPP designs were developed in two different companies using their own experience, approaches and available groundwork. This determined the presence of certain differences in the designs, but the design targets related to efficiency and safety are met.

Progress of Safety Systems in JSC Atomenergoproekt VVER-Type NPP Designs

NVNPP Unit 5

Small series

Government Order No 1026 of 28.12.92 and within the Environmentally Clear Energy National Program

Kudankulam NPP

Belene NPP

Novovoronezh-2 NPP

VVER-TOI NPP

U- 87 (V-320) → AES-92 → AES-2006 → VVER-TOI NPP

U- 87 (V-320)

- 3 trains of active safety systems;
- single containment shell;
- emergency heat removal via secondary circuit is limited in time by water inventory in DM water tanks;
- core damage after 2-3 hours in case of active safety systems failure

AES-92

- 4 trains of active safety systems;
- passive safety systems for all critical safety functions (CSF);
- double containment shell with controlled annulus;
- emergency heat removal via secondary circuit is not limited in time both in active and passive mode;
- long-term (not less than 24 hours) ability to prevent fuel damage beyond the limits specified for DBA;
- The Certificate of compliance with EUR requirements is granted

EUR EUROPEAN UTILITY REQUIREMENTS FOR LWR PLANTS

British Energy plc • Electricité de France • Energoatom • Fortum • Iberdrola • NRG • Rosenergoatom • SOGIN • swissnuclear • Tractebel • TVO • Vattenfall • VGB Powertech

CERTIFICATE

Клуб Европейских Эксплуатирующих Организаций (EUR) удостоверяет, что проект **ВВЭР АЭС–92** успешно прошел все этапы анализа на соответствие требованиям EUR при участии:
• Института «Атомэнергопроект», Москва
Генерального Проектировщика;
• ОКБ «Гидропресс»
Главного Конструктора РУ;
• РНЦ «Курчатовский Институт»
Научного Руководителя проекта;
• Концерна «Росэнергоатом»
Эксплуатирующей организации.

По итогам данного анализа организацией EUR опубликован специальный Том 3 EUR, посвященный проекту АЭС–92.

The European Utility Requirement (EUR) organisation certifies that the **VVER AES92** design has successfully passed all the steps of the analysis of compliance vs. EUR with contributions from:
• Institute "Atomenergoproekt" Moscow,
as overall designer;
• OKB "Gidropress",
as NSSS designer and constructor;
• Kurchatov Institute,
as scientific authority;
• Concern "Rosenergoatom",
as electricity producer.

Following this analysis, a specific subset of the EUR volume 3 dedicated to the AES92 project has been published by the EUR organisation.

l 24 2007, Bernard Roche, chairman of the EUR Steering Committee

преля 2007 г., Бернар Рош, Председатель Руководящего Комитета EUR

AES-2006

- 2 trains of active safety systems with internal redundancy;
- passive safety systems for all CSF;
- double protective containment with controlled annulus;
- emergency heat removal via secondary circuit is not limited in time both in active and passive mode;
- long-term (not less than 24 hours) ability to prevent fuel damage beyond the limits specified for DBA under blackout conditions without the operator's interference;
- assessment of the design compliance with EUR requirements together with EUR experts

VVER-TOI NPP

- 2 trains of active SS;
- passive SS for all CSF;
- double protective containment with controlled annulus;
- emergency heat removal via secondary circuit is not limited in time both in active and passive mode;
- ensuring enhanced Unit resistance to extreme external impacts;
- long-term (not less than 72 hours) ability to prevent fuel damage beyond the limits specified for DBA under blackout conditions without the operator's interference;
- assessment of the design compliance with EUR requirements together with EUR experts

Safety concept of modern VVER NPPs

Safety concept provides for :

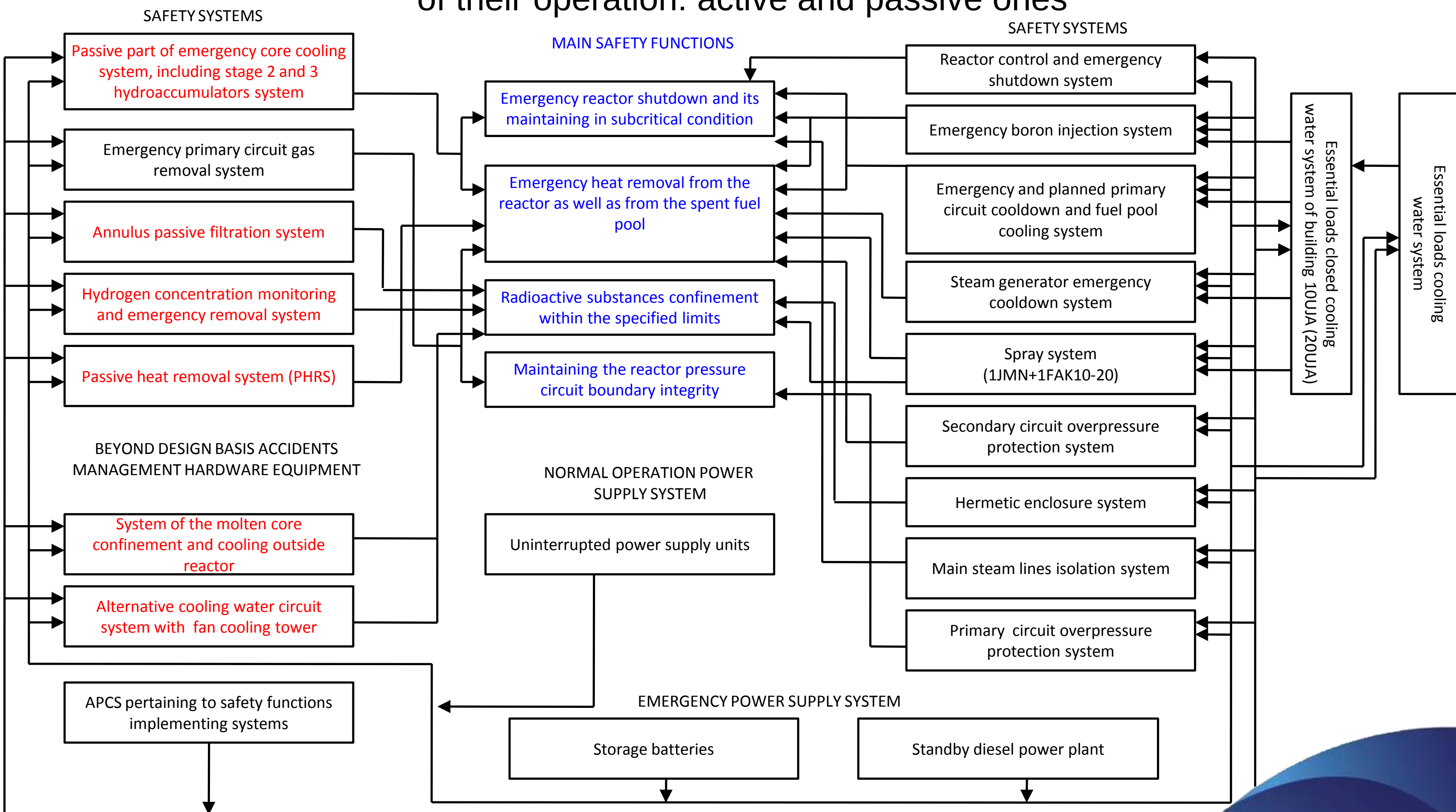
- ✓ Use of mutually redundant safety systems of «active» and «passive» principles of action that ensures protection against common-cause failures and allows for increase of safety systems reliability factors by several orders
- ✓ Use of «active» part of safety systems for normal operation functions that allows for increase of safety system availability level. Such solution provides for additional protection against common-cause failures and excludes latent failures being a main reason of system non-availability in standby mode.
- ✓ Safety systems are designed in such a way that operator interference in case of accident is not needed at least for first 15-30 minutes
- ✓ Protection against human errors due to: increase of automatic control level of systems (exclusion of personnel's actions) in case of occurrence of certain design-basis accidents and, in particular, in the case of primary-to-secondary leaks; use of passive systems, which activation do not require participation of operation personnel
- ✓ Use of full-pressure double shell containment with hydrogen removal systems, the catcher for molten core provide no exceeding of maximum release established values during beyond design-basis accidents with core severe damage

Comparison of main safety features

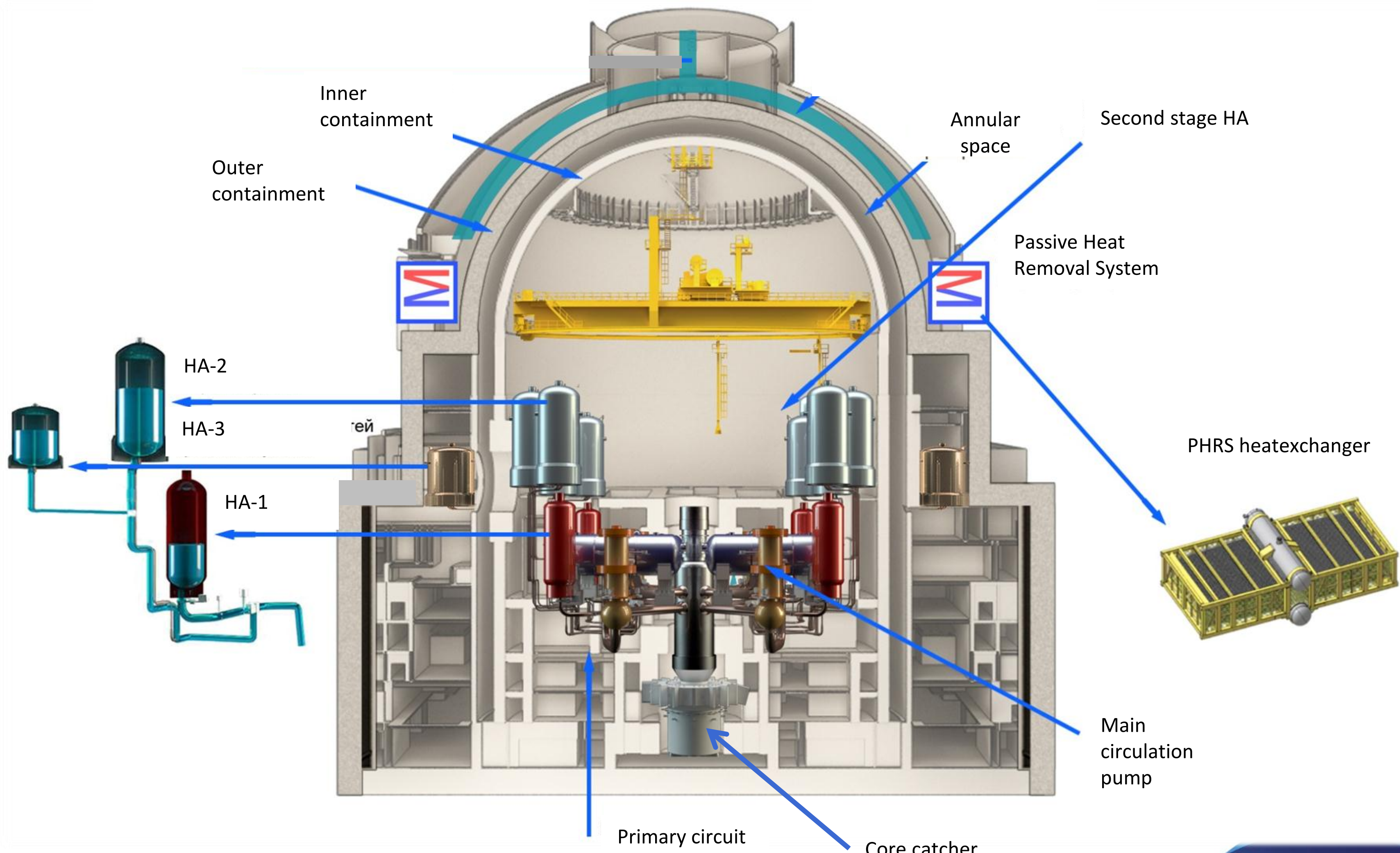
Safety systems	AES-2006 Saint Petersburg	AES-2006 Moscow
Number of active trains	4	2
Number of passive trains	4	4
GA-1	+	+
GA-2	-	+
Core Catcher	+	+
Emergency boron injection system	+	+
Passive heat removal system from SG	+	+
SG Emergency cool-down system	+ (open)	+(closed loop)
Passive containment heat removal system	+	-
Active containment heat removal system	+	+
Containment hydrogen removal system	+	+
Annulus passive filtering system	-	+

Main Engineering Solutions for Safety Systems

The safety assurance concept is based on applying safety systems that use different principles of their operation: active and passive ones



Main passive safety systems



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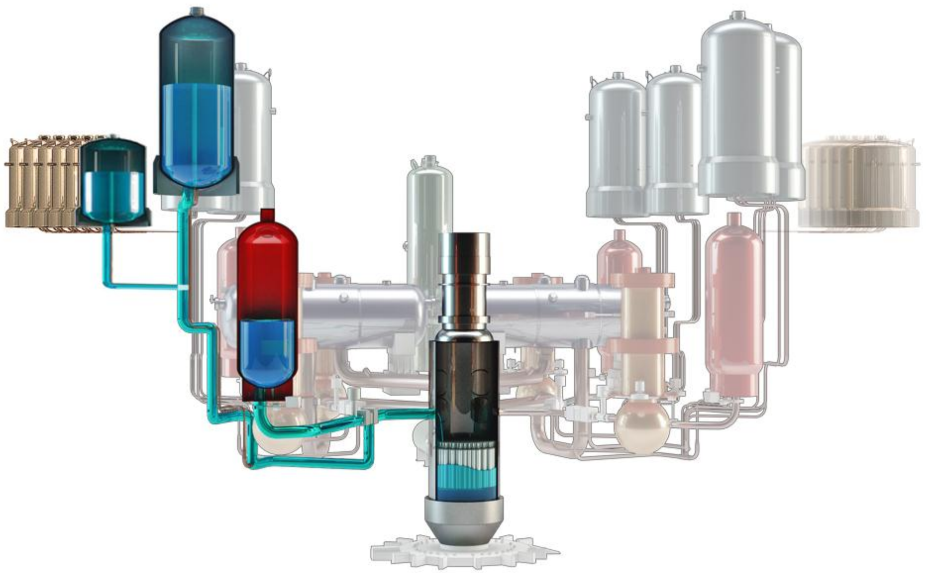
Предприятие Госкорпорации «Росатом»

Passive core flooding system



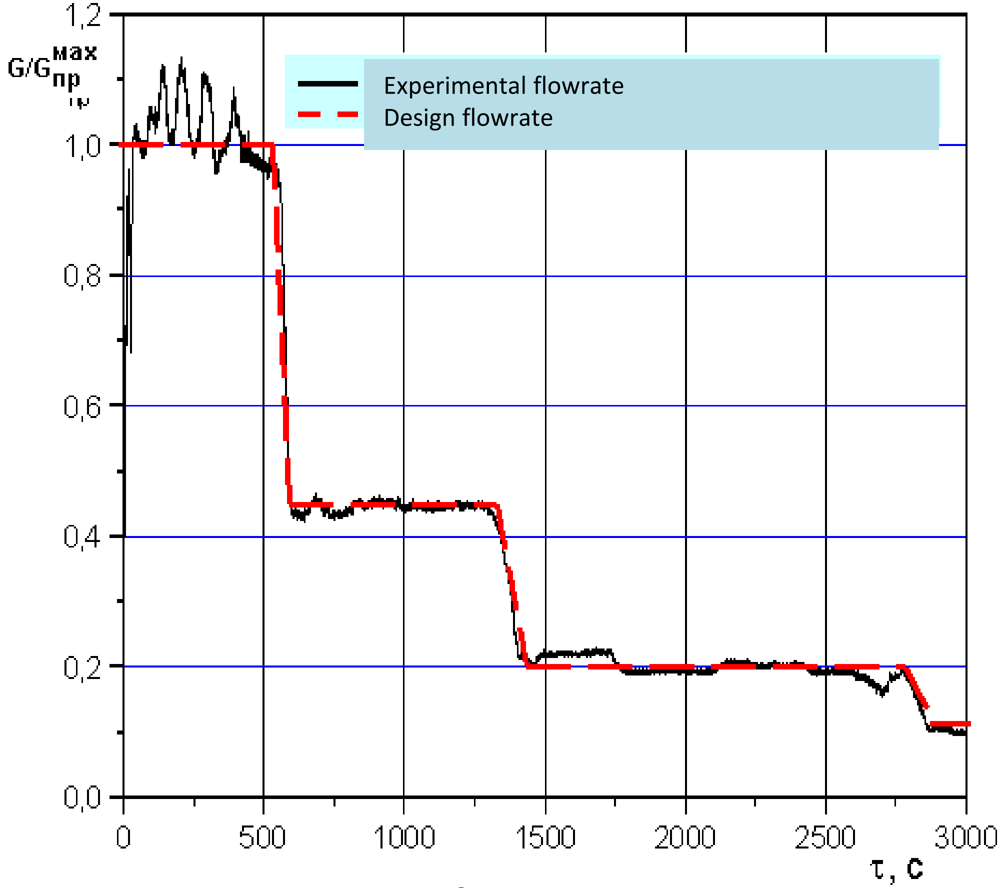
Core flooding system is a passive part of emergency core cooling system (ECCS) consisting of hydraulic accumulators (HA) of the 1st, 2nd and 3rd stages.

HA-1 are required for emergency flooding of the core with boric acid solution if primary pressure goes below 5.9 MPa.

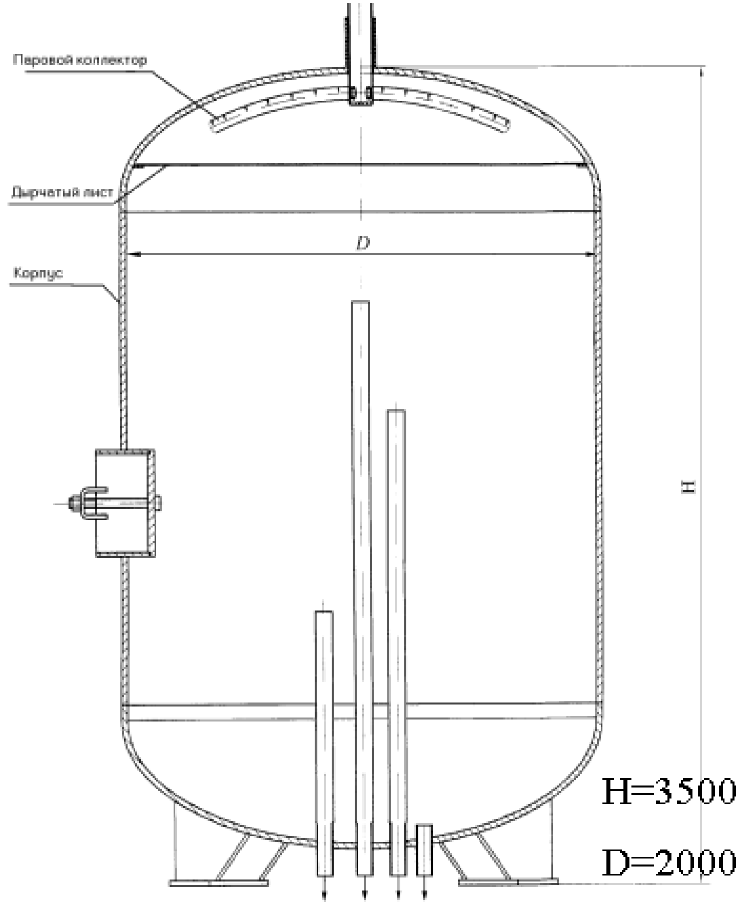
HA-2 are used to maintain coolant inventory in the primary circuit required for reliable heat removal from the core. They start delivering water when primary pressure drops below 1,5, MPa**.**

HA-3 are a “followup” of HA-2 to maintain coolant inventory in the reactor core under beyond design basis accidents with primary circuit leaks and failures of the active safety systems after the expiration of boric acid solution inventory in HA-2.

Results of HA-2 tests at the test bench



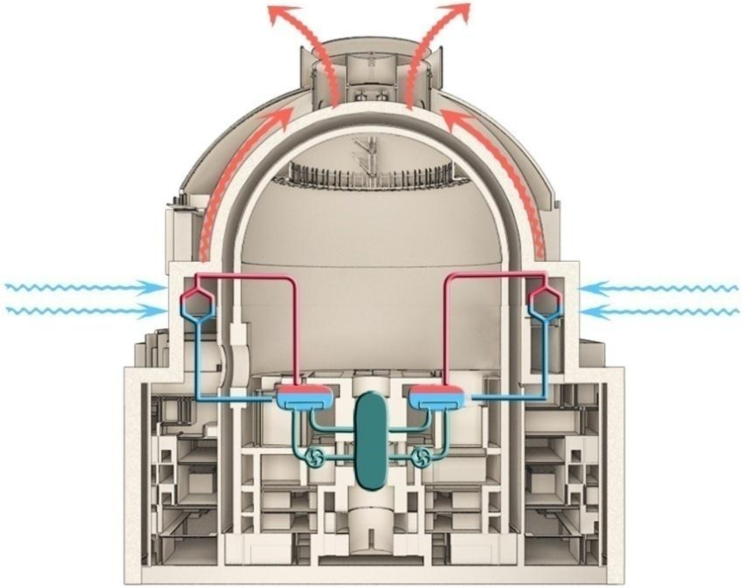
Flow rate



Test volume

Passive Heat Removal System

Passive heat removal system (PHRS) is designed for long-term removal of decay heat from the reactor in case of loss of all electrical power supply sources including emergency ones in case of leak-tight primary circuit and leakages as well.



The system comprises of four independent natural-circulation secondary coolant circuits (4 x 33 %) – one for each circulation loop of the Reactor plant

Each circuit comprises of heat-exchange modules, steam-condensate path pipelines, air ducts for ambient air supply and heated air bleeding and passive direct-action devices intended to control air flow rate.

The heat exchangers are placed at a height of around 40 m and are protected by civil structures, so that their possible failure caused by floods or other natural or man-induced effects (air shock waves resulted from explosions at the site and the adjacent territories, as well as hurricanes and tornadoes) is excluded

PHRS arrangement in Kudankulam NPP containment

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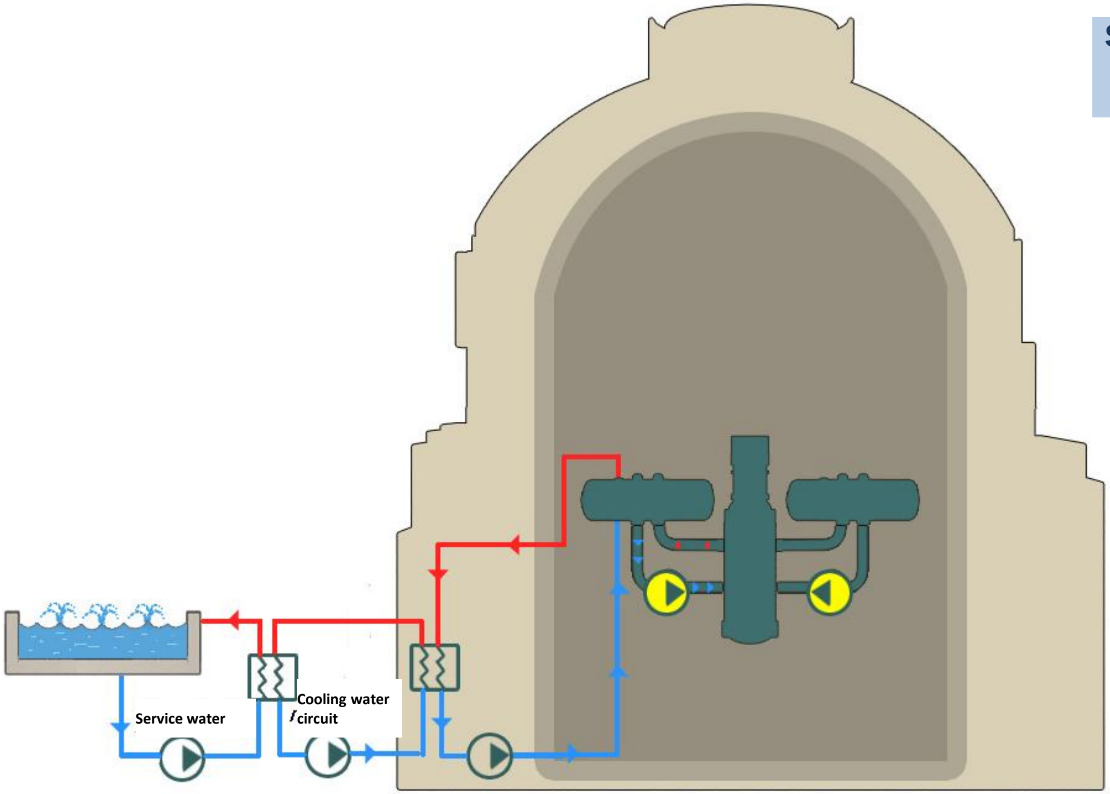
Предприятие Госкорпорации «Росатом»

Steam Generator Emergency Cooldown System



SG Emergency Cool-down System	Closed-loop active system

Steam generator (SG) emergency cooling system is designed for performing the following safety functions under design basis accidents:

- ✓ decay heat removal from the core in emergency situations associated with loss of power supply or loss of normal heat removal through the secondary circuit including steamline and feedline leaks
- ✓ decay heat removal from the core and reactor cooling down in emergency situations related with depressurization of the primary circuit including rupture of the main circulation pipeline (through intact loops)

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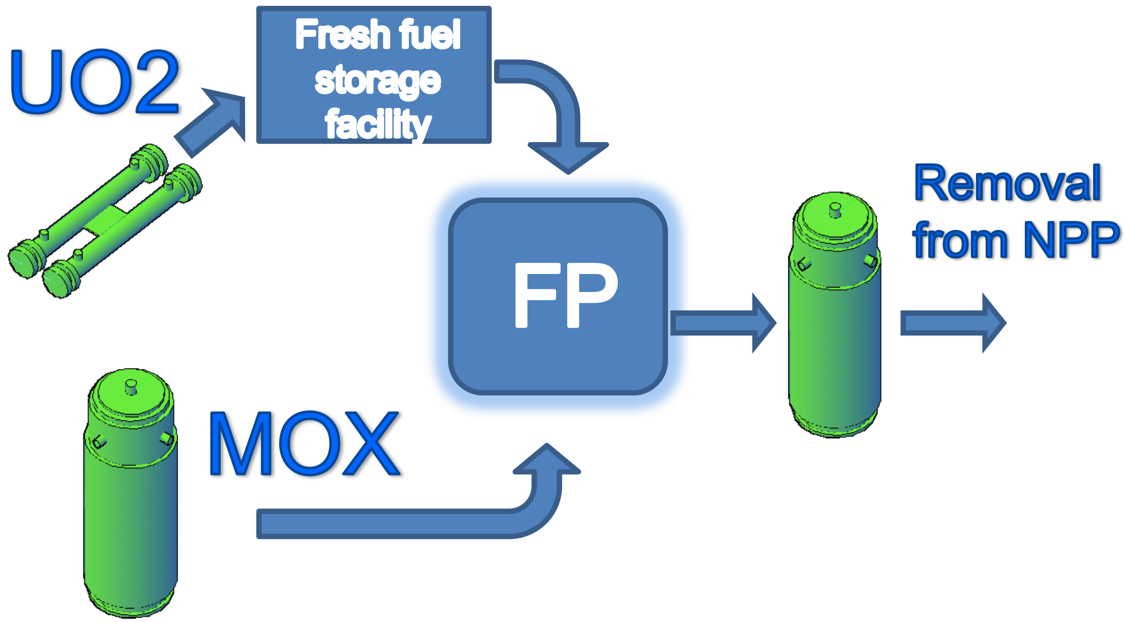
Design options for VVER-TOI - MOX-Fuel

The proposed fuel handling concept and the solutions accepted in the VVER-TOI design make it possible to provide the following in case of the MOX-fuel use:

- ✓ not to rework the fresh fuel storage facility for MOX FA
- ✓ not to upgrade the reactor building systems



- ✓ with no additional equipment development and manufacture to deliver safely new MOX FA to the reactor building, to load them into the reactor and to remove the spent MOX FA

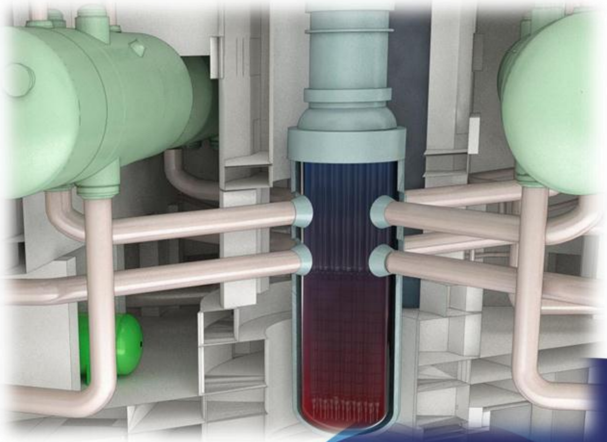
Design options for VVER-TOI - Load Following Operation

The design provides for the Power Unit load following operation within the range of 100-50-100 according to the daily load programme during the whole time of the fuel hold-up operation with the constraints as follows:

- ✓ During the initial time of the fuel hold-up operation the load following is prohibited – 40 days – fuel side (fuel supplier) restrictions;
- ✓ Within 60 to 80% of the fuel hold-up operation time the power decrease rate – 3% per minute and the power increase rate – 1% per minute – can be provided;
- ✓ At the final stage of the fuel hold-up operation the load following is inadvisable or the power decrease rate 3% per minute can be provided, then the power increase rate will go down from 1% per minute to 0.2%. If the off-loading intensity is reduced the power ascension rate can be increased up to 1% per minute

For the purpose of the load-following operation realization the following have been implemented in the Project:

- ✓ “Mild” temperature control due to the SG pressure change from 0.2 to 0.5 MPa;
- ✓ Algorithms using groups of control rods with reduced worth;
- ✓ The required capacity of the boron control system and the coolant processing system is provided



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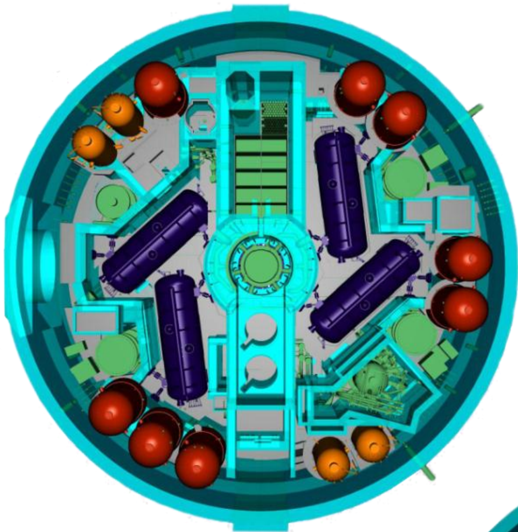
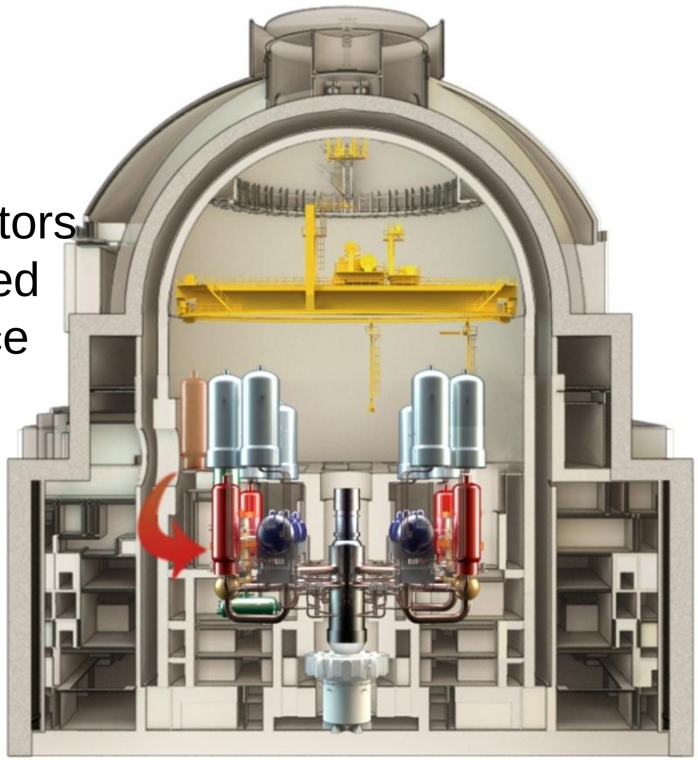
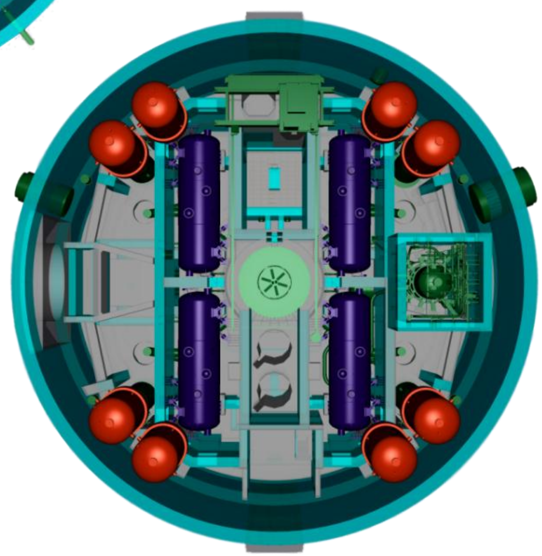
Optimization of Reactor Building Layout Concepts

NVO NPP-2 Layout



VVER-TOI -
1st stage ECCS hydro accumulators have been moved below the service elevation





VVER-TOI –
“mirror layout”

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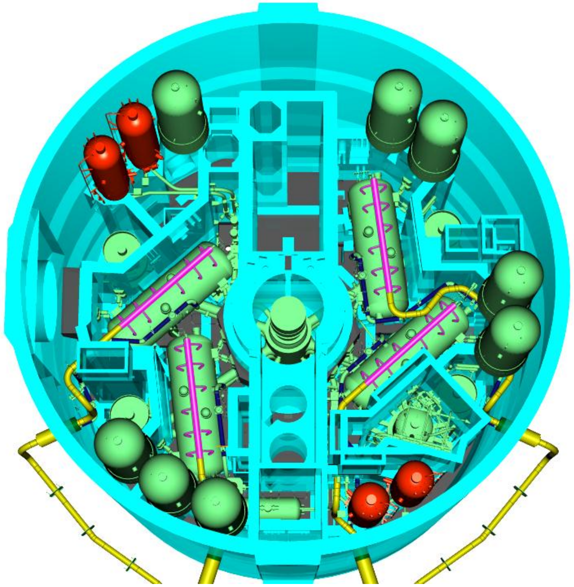
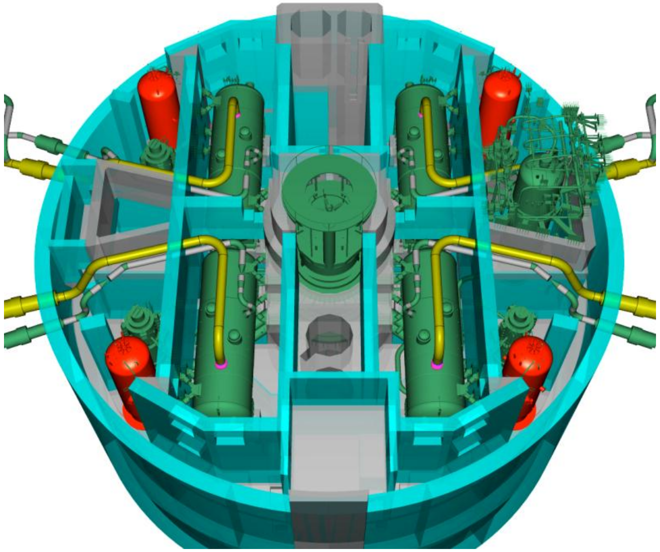
Optimization of Reactor Building Layout Concepts

NVO NPP-2 Layout



VVER-TOI – “mirror layout”

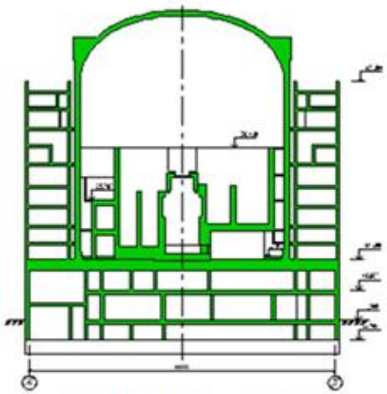


Steam chambers side location made it possible to rearrange completely the around-structures at the upper elevations as well as to balance the length of steam lines from all steam generators to FSIV, thus causing the balancing of hydraulic losses and of medium parameters of the steam lines

Pressure losses of steam lines have been minimized by excluding the steam header from the steam generator steam path

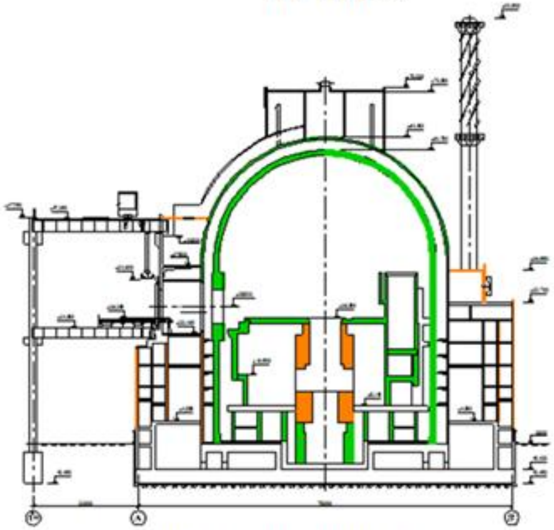
Evolution of Approaches to Reactor Building Civil Structures Erection

RPV-320-type NPP



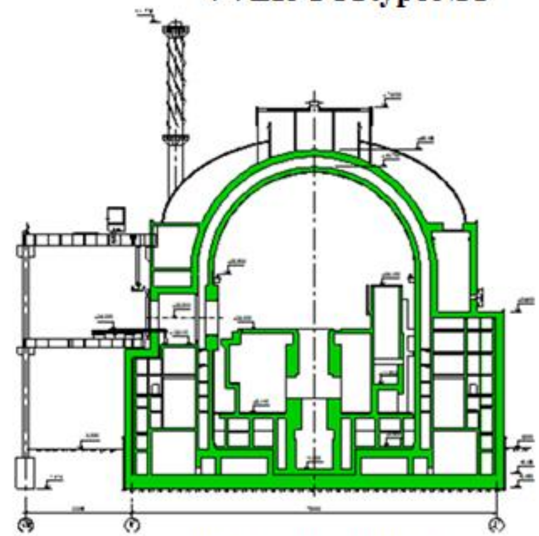
Construction time – 46 months, Implemented with Unit 3 of Zaporozhskaya NPP

NV NPP-2



Schedule construction time – 52.5 months for the first two Units

VVER-TOI type NPP



Schedule construction time – 48 months for the main Unit, 40 months for next Units

(white)	- reinforcement with individual bars
(orange)	- reinforcement with spatial frameworks
(green)	- reinforcement with reinforced form assemblies with retained frameworks

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Summary

Modern designs of VVER Gen III (III+) feature a perfect blend of safety technology, reliability and economic performance.

Further increase of NPP performance can be obtained by increasing working parameters resulting in higher coefficients of efficiency

Thank you for your attention!

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