РОСАТОМ

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

VVER NPP experience and development. MIR.1200 project

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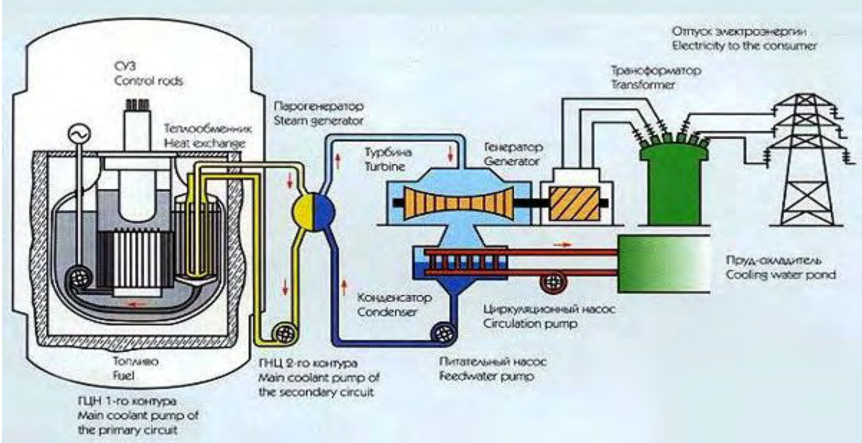
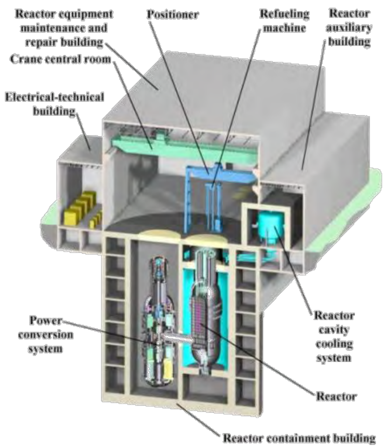
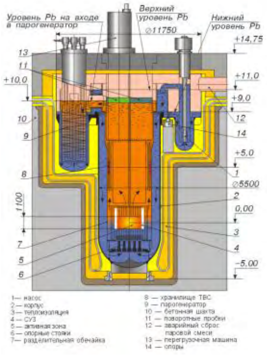
Nuclear Reactors Technologies under developing in State Corporation Rosatom

Present Russian Nuclear Reactors Technologies:

1. **Light-water reactors *(VVER, VBER, etc.)***
2. **Gas-cooled reactors (GT-MGR, VTGR)**
3. **Metal-cooled reactors *(BN, etc.)***







These reactors were designed for

installation for wide range conditions

Evolution of VVER focusing on field-proven technology, compliance with modern international safety requirements and using reference and tested design solutions

Gen1 VVER-440[1], 70-ies
➔Gen2 VVER-440, 70-80-ies
➔Gen2 VVER-1000, 80-90-ies

➔ VVER-1000[2]
Generation 3
90-ies/ 2000th

➔ VVER-1200[3]
Generation 3+
2000/2010th

➔ VVER-1200+ [4]
Generation 3+
New export version

- Corium trap and double-wall containment
- Four- train principle of safety system
- First use of a digital instrumentation and control system
- Core nuclear physics parameter improved
- Measures to improve earthquake resistance
- Adoption of the "leak before break" concept
- Improved protection against external hazards and air plane crashes
- Principle of diversity with passive safety features
- Advanced safety features e.g. heat removal
- Design in compliance with EUR
- Core damage frequency: $<10^{-5}$

Gen3 VVER-1000 and VVER-640: Compliance with international safety standards

- Life time is 60 years
- Enhanced power and efficiency
- Improved Operation & Maintenance
- Exclusive use of digital I&C equipment
- Advanced passive residual heat removal systems for severe accidents
- Improved reliability of safety systems
- More efficient use of fuel
- Modified fuel elements
- Core damage frequency: 10^{-6}

Gen3+ VVER-1200: Improved safety & economics

- Transition to the design in compliance with the Western standards and regulations
- Taking into account severe accident consequences (incl. Fukushima NPP scenario) for preventing radioactive releases
- Higher efficiency of implementation (higher automation of designing process and project management) and life cycle management
- Increasing the number of components manufactured in EU
- Core damage frequency: 10^{-6}

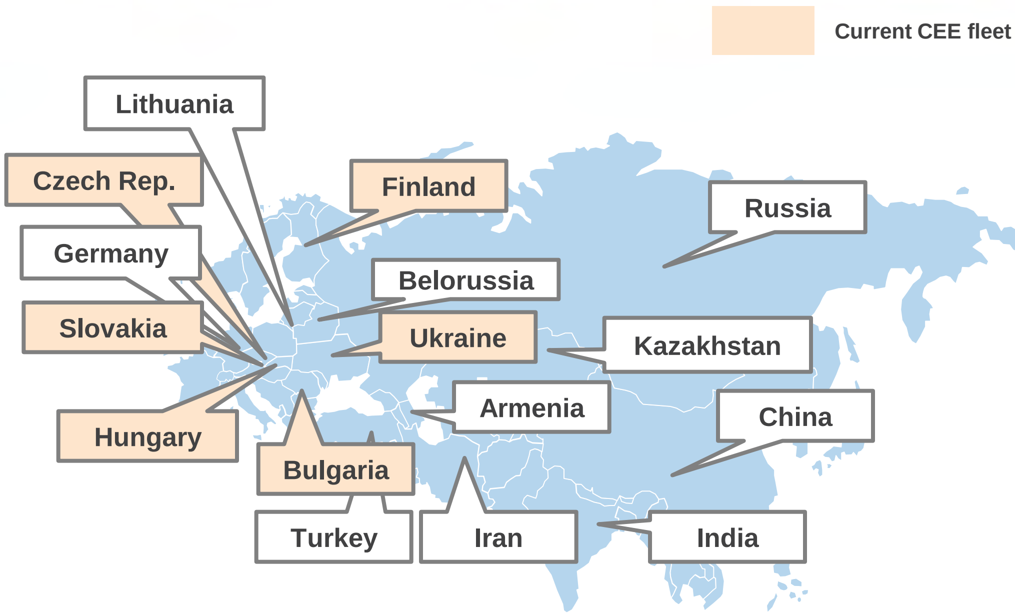
Gen3+ VVER-1200 +: Compliance with the Western regulations & supply models

1) Gen1 VVER 440 (Reactor Model: V 230),
Gen2 VVER-440 (Reactor Model: V 213 installed at the sites located in Russia, Czech Republic, Slovak Republic, Ukraine, Hungary, Bulgaria),
VVER 1000 (Reactor Model: V 320 installed at the sites located in Russia, Czech Republic, Ukraine, Bulgaria)
2) Gen 3 VVER-1000 AES-91 Reactor Model: V 428 for Tianwan NPP and V-466 for BID OL3 (NPP design named VVER 91/99)
AES-92 Reactor Model: V 392 for Kudankulam NPP, V-466 for Belene NPP
VVER-640 (Reactor model V-407 project created for developing regions export. It was licensed for construction for Leningrad site. Project was stopped because of Russian financial crisis in 1998)
3) Gen 3+ VVER-1200 Reactor model V 392M (AES 2006/92 Novovoronezh NPP-2, Akkuyu NPP)
4) Gen 3+ VVER-1200+ Reactor model V-491 AES-2006/91 Leningrad NPP-2, Baltic NPP, Belorussia NPP, Temelin NPP (BID), Paks 3,4 (BID preparation), Loviisa 3 (BID preparation))

VVER 440/1000 designs were developed for implementation in the Russia, Europe and Asia regions

Russian nuclear reactors worldwide

Russia	Globally	Total
Constructed		
36	56	92
Under current Rosatom operation		
32	-	32
In Progress		
10	**15**	**25**

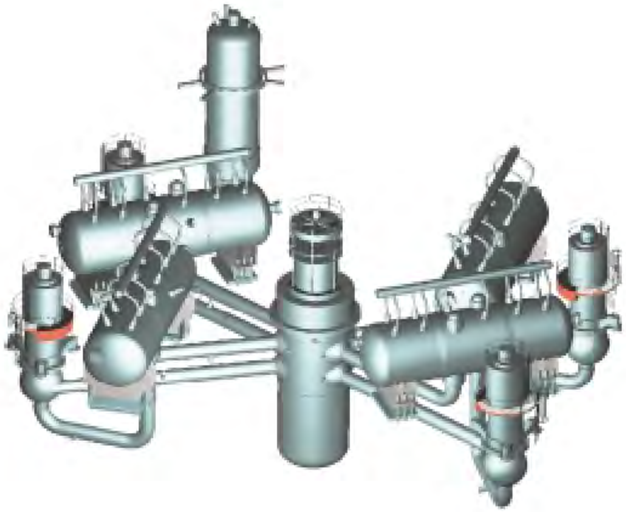


Strong Reference and Challenging Perspectives

- More than 30 units of installed fleet
- 6 more units being in progress
- ≥ 6 units pending by the customer

Two operating VVER-1000 power units at Tianwan NPP in China

VVER NPP defense-in-depth barriers



FUEL ELEMENT CLADDING

Preventing of fission product release to coolant of primary circuit

PRIMARY CIRCUIT

Preventing of fission product release to containment

SYSTEM OF PROTECTIVE TIGHT ENCLOSURES

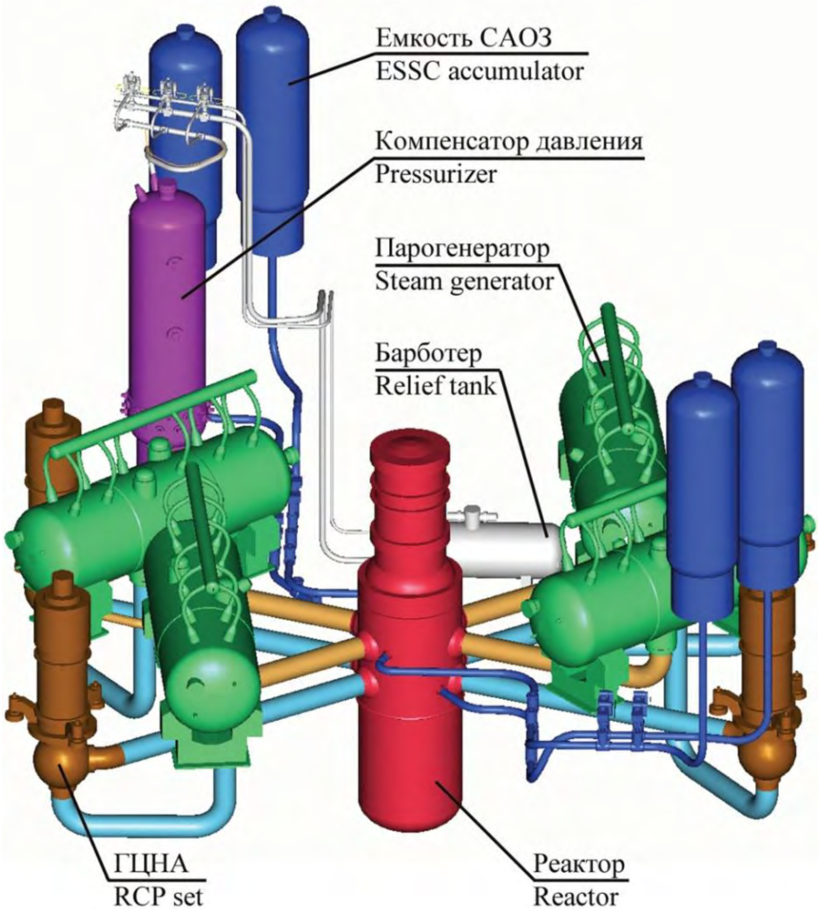
Preventing of fission product release to environment

VVER Nuclear Steam Supply System standard design equipment

Primary coolant circuit system with horizontal steam generators

1. Thermal power – 3200 MW
2. Primary coolant circuit configuration – 4 loops
3. Operation lifetime – 60 years
4. SSE (SL-2) Seismic loads – 0.25 g
5. The intentional crash of a commercial airplane is considered
6. Availability factor - 92%

All equipment designed for railway trasportation.



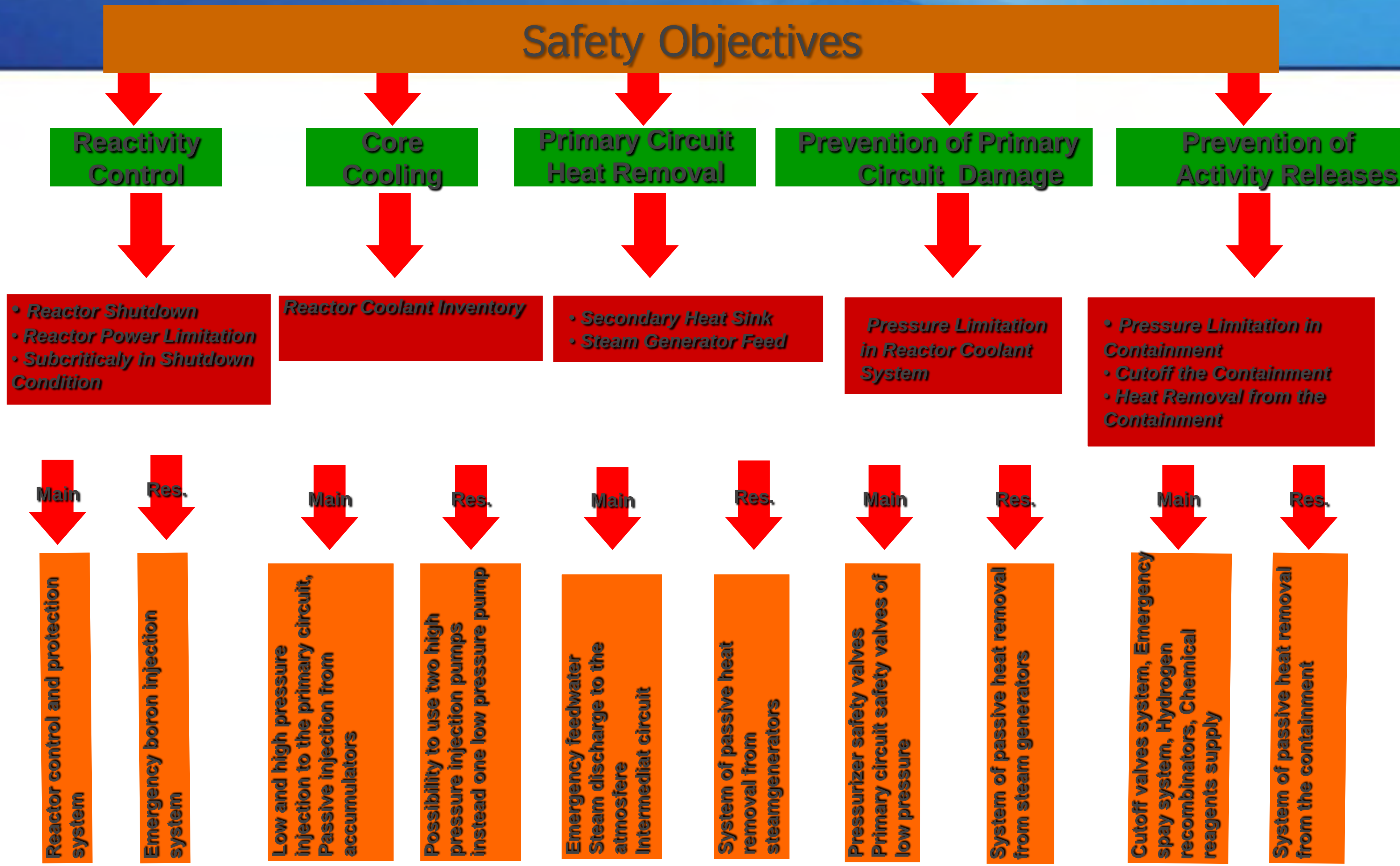
Main technology parameters evolution within reference technology

Parameter	VVER-1000	VVER-1200
Nominal thermal power of the reactor, MW	3000	3200
Load factor	0,78	0,92*
Coolant pressure at the reactor outlet, MPa	15,7	16,2
Coolant temperature at the reactor inlet, °C	290	298,6
Coolant temperature at the reactor outlet, °C	319,6	329,7
Maximum linear heat rate, W/cm	448	420
Pressure at the outlet of SG steam header (absolute), MPa	6,27	7,0
Primary design pressure, MPa	17,64	17,64
Secondary design pressure, MPa	7,84	8,1
FA-maximum burnup fraction of fuel in FAs withdrawn (in the base equilibrium fuel cycle), MW day/kgU	55	up to 70*
FA-averaged burnup fraction of fuel in FAs withdrawn (in the base equilibrium fuel cycle), MW day/kgU	49	55
Period between refuellings, months	12	12/(18-24)*
Time of fuel residence in the core, year	4	4/5*

Fuel parameters evolution

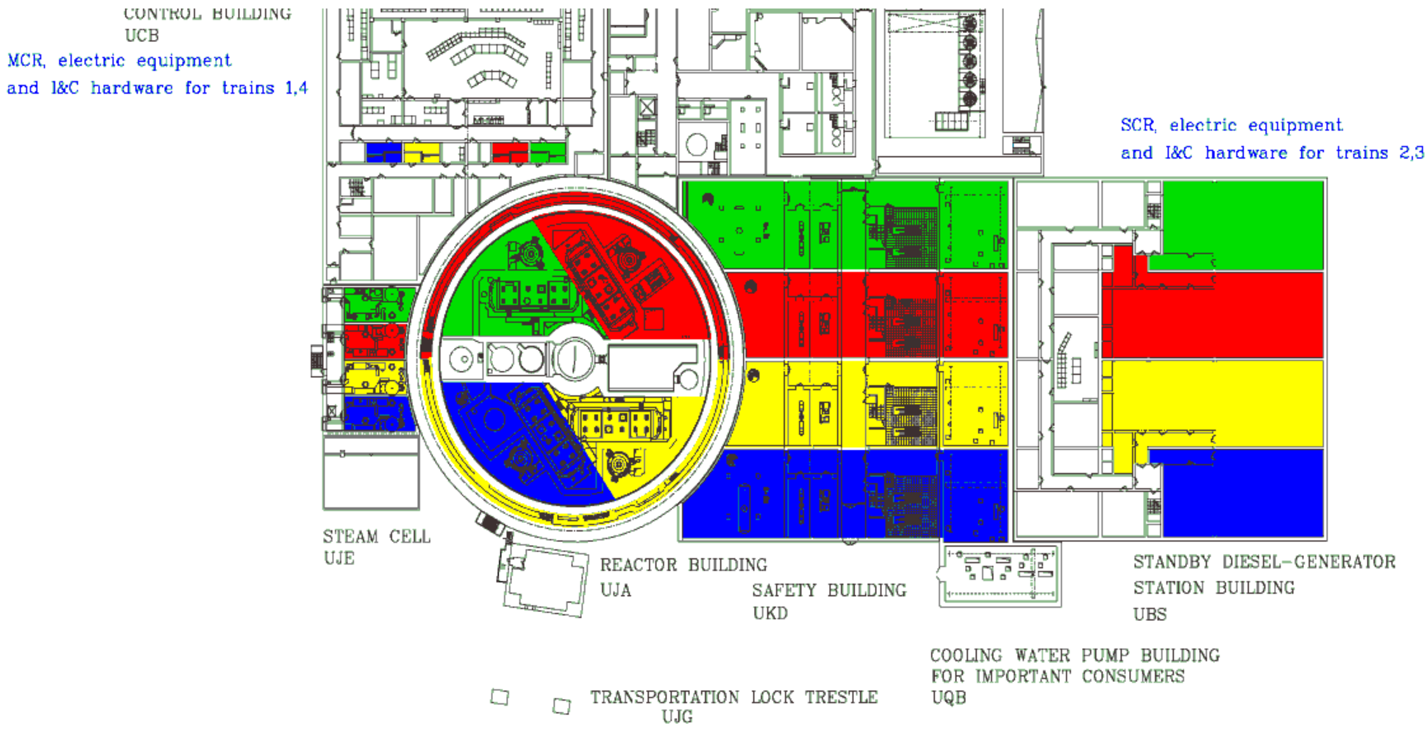
	before 1997	1998-2000	from 1998	from 2003	from 2006	
FA type	TVS (TVS-M)	UTVS	TVSA	TVS-2	TVSA-ALFA TVS-2M	
Bundle type	DBA	U-Gd	U-Gd		U-Gd	
Reload batch average enrichment, % U^{235}	4,31	3,77	~4,26		4,83	4,88
FA quantity in reload batch, pcs.	54	48	42	54	36	60
FA burnup, MW×days/kgU	49	49	55		68	
Fuel cycle	3-year	3-year	4·(310-320) EFPD	3·(350-370) EFPD	5·(310-320) EFPD	3·(480-510) EFPD
Natural Uranium consumption kg/MW×days	0,240	0,205	0,199	0,210	0,193…0,187	

VVER NPP safety objectives



VVER NPP safety systems for design basis accident protection

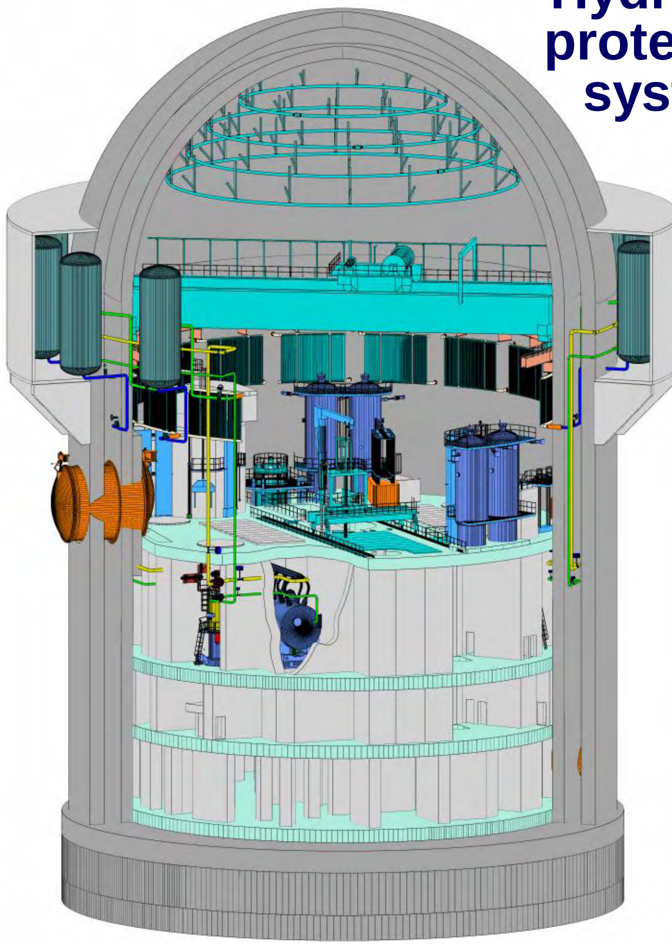
4x100% separated active safety systems



VVER NPP safety systems for severe accident management

The structures, systems and components fulfilling safety functions used in postulated core melt accidents (level 4 of Defense in Depth) are practically independent from the structures, systems and components used to prevent core melt accidents.

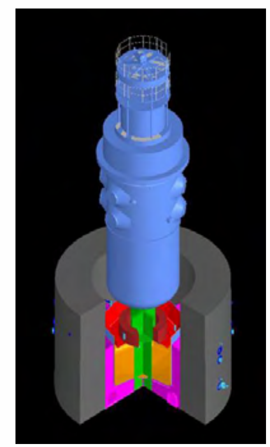
Active parts of the systems and components necessary for ensuring the containment function in a core melt accident are fulfil the single failure criterion



Hydrogen protection system

Passive heat removal system

Ex-vessel Core Catcher



Probabilistic Design Criteria

- **Total core meltdown frequency less than 10^{-5} 1/plant-yr;**
- **Exclusion of accident scenarios, which can lead to large release at an early stage of an accident;**
- **Total limiting accident release frequency less than 10^{-7} 1/plant-yr.**

PSA Results for VVER-1000 Tianwan NPP operating in China:

1. Average total core damage frequency during power operation of power unit	$2.67*10^{-6}$
2. Average total core damage frequency during shutdown regimes	$7.2*10^{-7}$
3. Average total core damage frequency for internal initiating events	$3.39*10^{-6}$
4. Total limiting accident release frequency	$6,3*10^{-8}$