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OECD/NEA Workshop on Innovations in Water-cooled Reactor Technologies

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SMALL MODULAR REACTORS

ENGINEERING SOLUTIONS FOR SAFETY PROVISION

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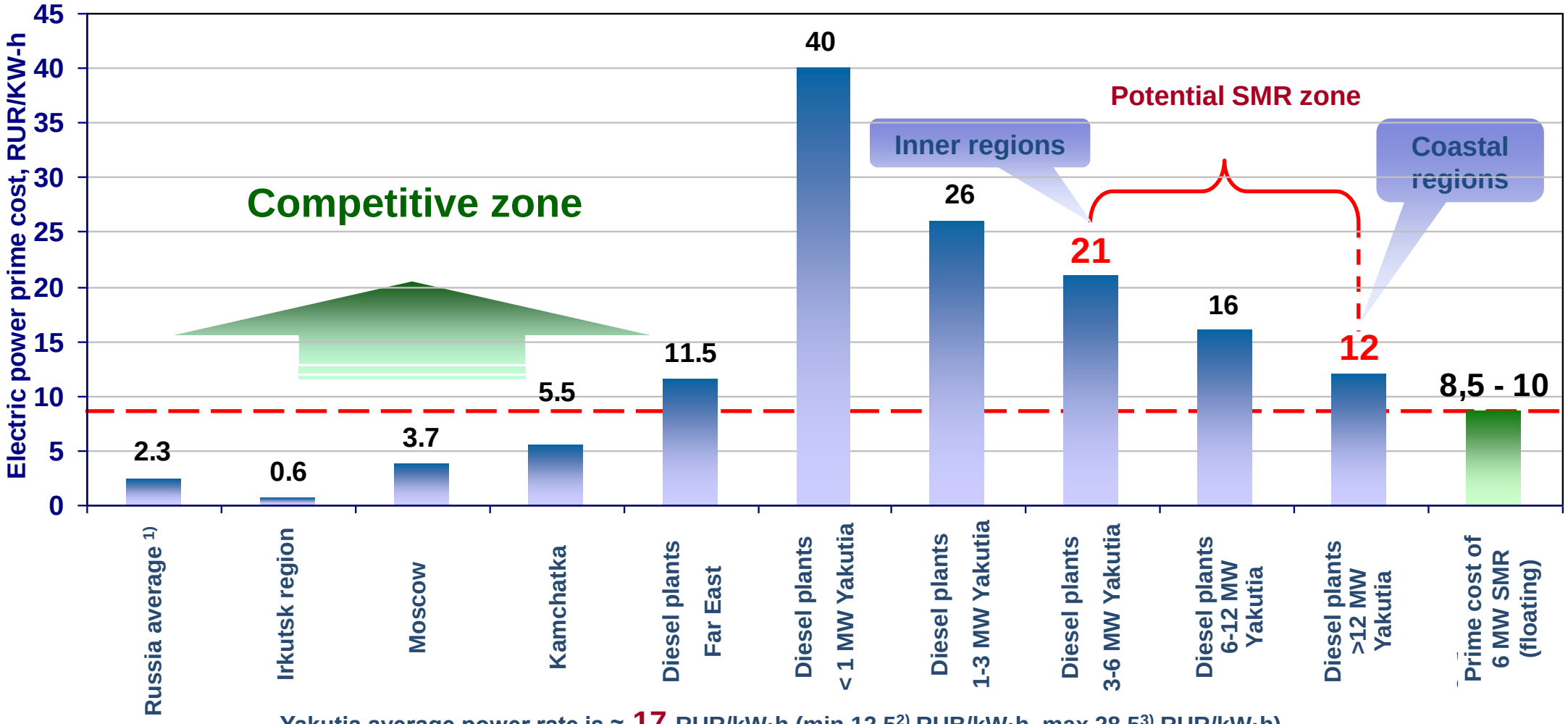
SMALL AND MEDIUM REACTORS PROSPECTS

Small and medium reactors have a significant potential for developing new and economically promising market segments for nuclear power	
Small reactors	**Medium reactors**
In the remote or isolated regions where the hydrocarbon fuel delivery cost is very high, electricity grids are either absent or underdeveloped	In the regions where big capacities are not required, consumers are setting demands for reliable electricity supply systems; cost of gas, fuel oil and coal are dominating in the regional budgets

Classification of SMRs	
Classification	**Notes**
1 By electric power of single power unit (IAEA classification)	Small reactors – up to 300 MWe Medium reactors – between 300 and 700 MWe
2 By energy consumption sectors	For Russia it means: Local Sector (1-20MWe) - isolated from the Russian energy system and other energy sources; consists of one source and one or several consumers Territorial Sector (20-100MWe) - centralized; isolated from the Russian energy system; consists of several sources and consumers Regional Sector (100-700MWe) - centralized; consists of balanced sources and consumers; connected to the Russian energy system

- **IMPLEMENTATION OF SMRs MATCHES THE DEVELOPMENT STRATEGY OF THE ARCTIC AREA**
- **IMPLEMENTATION OF SMRs IS A PROMISING AREA WITH ITS OWN MARKET NICHE**

SMALL MODULAR REACTORS COMPETITIVE CONDITIONS



Yakutia average power rate is ≈ 17 RUR/kW·h (min 12.5[2] RUB/kW·h, max 28.5[3] RUR/kW·h)

1) FEDERAL TARIF SERVICE (FTC, RUSSIA). Order. On maximum tariff level for electric power for 2014, No. 185-e/1 dated October 11, 2013.
2) Decree on fixing of tariffs for electric power supplied by JSC "Sakhaenergo" in 2013 Nos. 211 and 212 dated December 20, 2012, Yakutsk (for Chersky and Zeleny Mys settlements and Ugolnoe village, Verkhnekolymsky ulus)
3) Decree on fixing of tariffs for electric power produced by JSC "Sakhaenergo" in 2013, No. 204 dated December 18, 2012 Yakutsk (all over Yakutia)

OKBM Afrikantov SMR development engineering basis

Wide experience in naval nuclear propulsion plants development and operation

Operating experience > 6 500 reactor-years

Wide experience in development and operation of nuclear propulsion plants for icebreakers

Number of RPs – 20 (including 8 operating nuclear icebreakers)
More than 50 years of 3 nuclear icebreakers generations in Arctic
Operating experience > 365 reactor-years

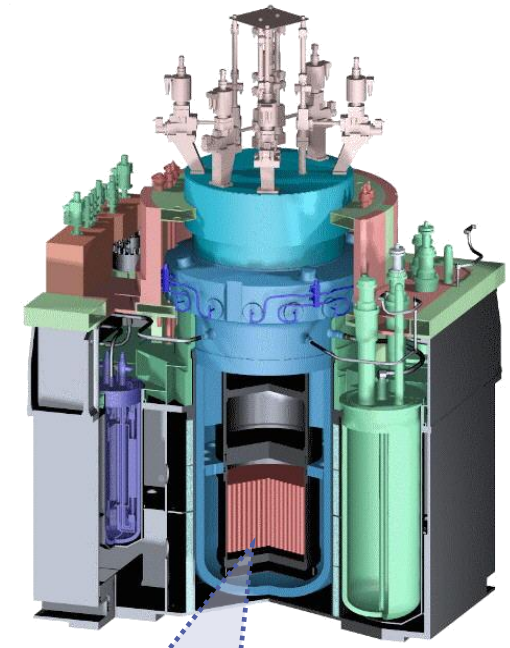
Experience in reactor plants design and procurement for floating nuclear power unit

Experience in design, licensing and construction of KLT-40S floating power unit

We have proven reactor technologies and innovative solutions

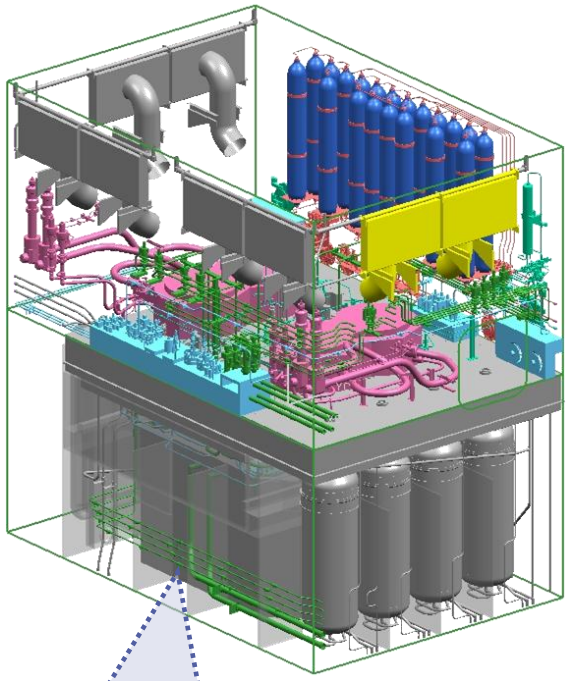
OKBM AFRIKANTOV SMALL MODULAR REACTORS

ABV-6M



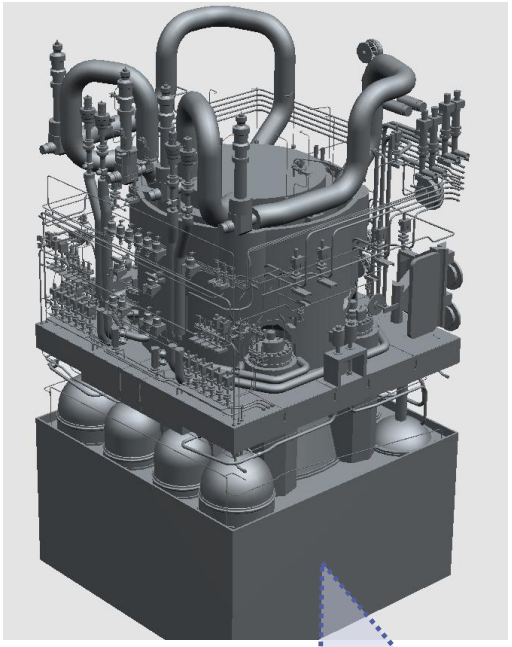
Thermal power 16-45 MW
Electric power 4-10 MW
Integral type reactor with 100 % primary circuit natural circulation for stationary and floating NPPs

KLT-40S



Thermal power 150 MW
Electric power 38,5 MW
Serial modular reactor for nuclear icebreakers and freight ships, stationary and floating NPPs

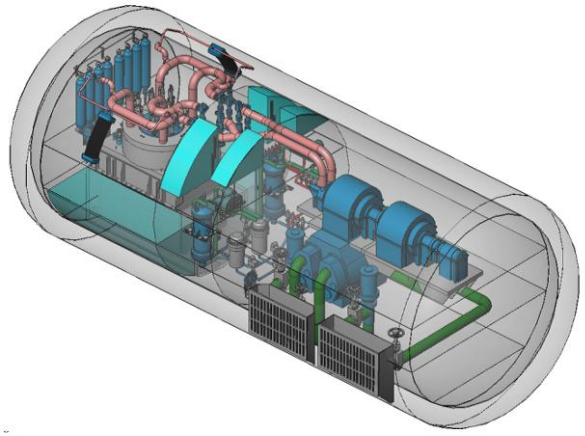
RITM-200M



Thermal power 175 MW
Electric power ~ 50 MW
Integral type reactor with forced circulation for nuclear icebreakers, stationary and floating NPPs

SMALL MODULAR REACTORS APPLICATIONS

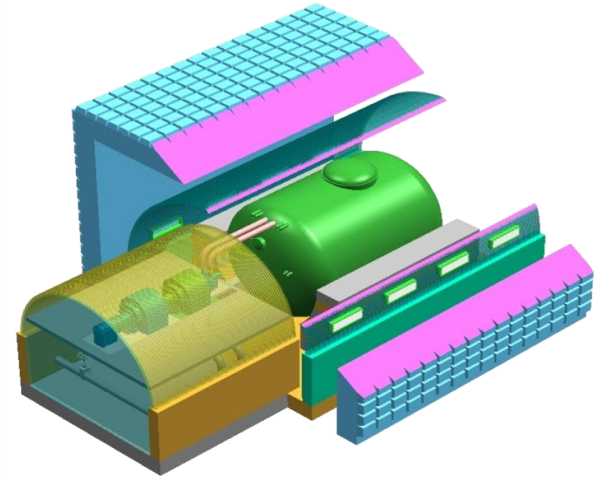
FLOATING POWER UNITS TO SUPPLY HEAT AND POWER TO THE CONSUMERS IN COASTAL ZONE OF HARD-TO-REACH AREAS



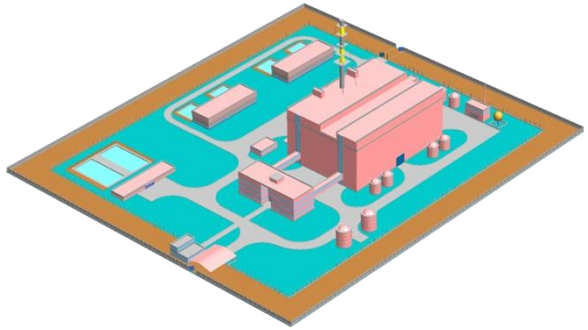
SUBSEA NUCLEAR POWER UNITS

FLOATING NUCLEAR DESALINATION COMPLEXES

AUTONOMOUS POWER SUPPLY FOR OFFSHORE OIL PLATFORMS



MODULAR TRANSPORTABLE POWER UNITS



GROUND-BASED PLANTS FOR AUTONOMOUS POWER SUPPLY

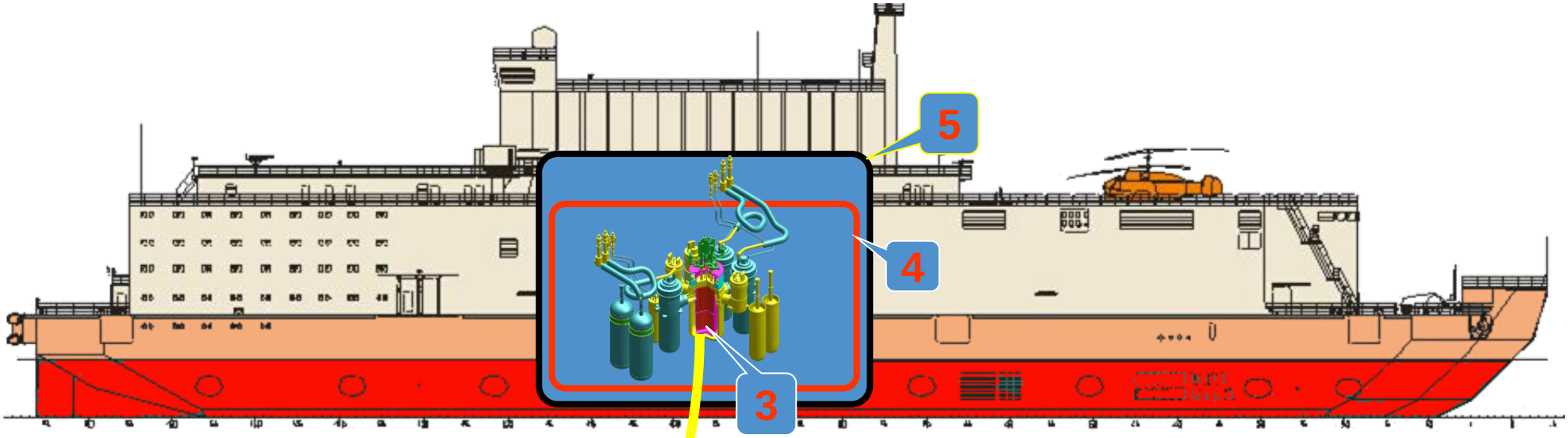
SAFETY CONCEPT:

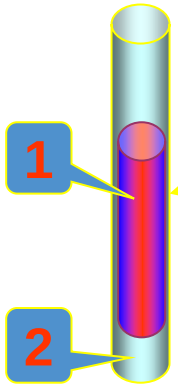
- Defense-in-depth
- Inherent safety features
- Engineered safety features and procedures including:
    - passive safety systems
    - self-actuating devices
    - proven engineering practices and up-to-date design experience

INHERENT SAFETY FEATURES:

- Negative reactivity coefficients on fuel and coolant temperature and on steam density and integral power
- High thermal conductivity of the fuel composition defining its relatively low temperature
- Natural circulation in the reactor coolant system and EHRS passive channels
- Insertion of control rods into the core under the force of springs (scram rods) or gravity (shim rods) in case CRDMs are de-energized
- High thermal capacity of the reactor primary coolant system components and structures
- High mechanical stress margin on the reactor coolant system pressure
- Compact modular and leaktight design excluding long and large diameter RCS pipelines

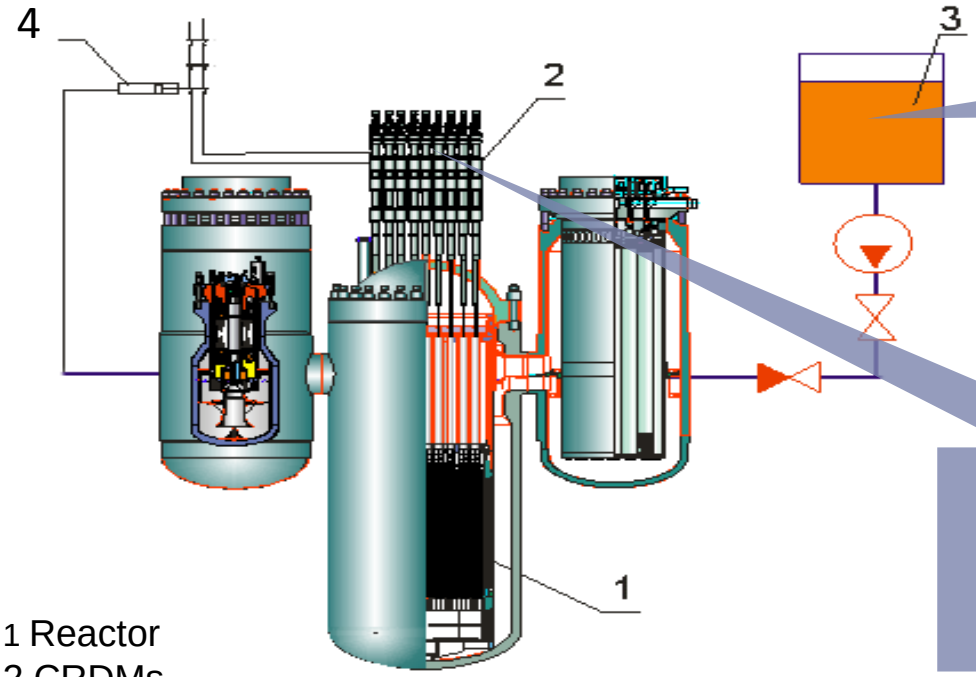
PHYSICAL SAFETY BARRIERS





1 – FUEL COMPOSITION
2 – FUEL CLADDING
3 – RCS PRESSURE BOUNDARY
4 – PLANT CONTAINMENT
5 – PROTECTIVE ENCLOSURE

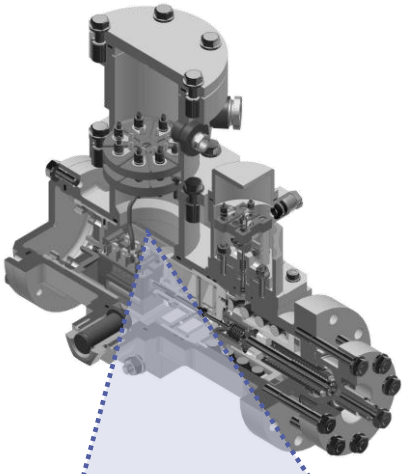
EMERGENCY REACTOR SHUTDOWN SYSTEMS



Soluble absorber injection system

Electro-mechanical reactivity control system

1 Reactor
2 CRDMs
3 Soluble absorber injection system
4 Pressure-actuated electric circuit-breaker



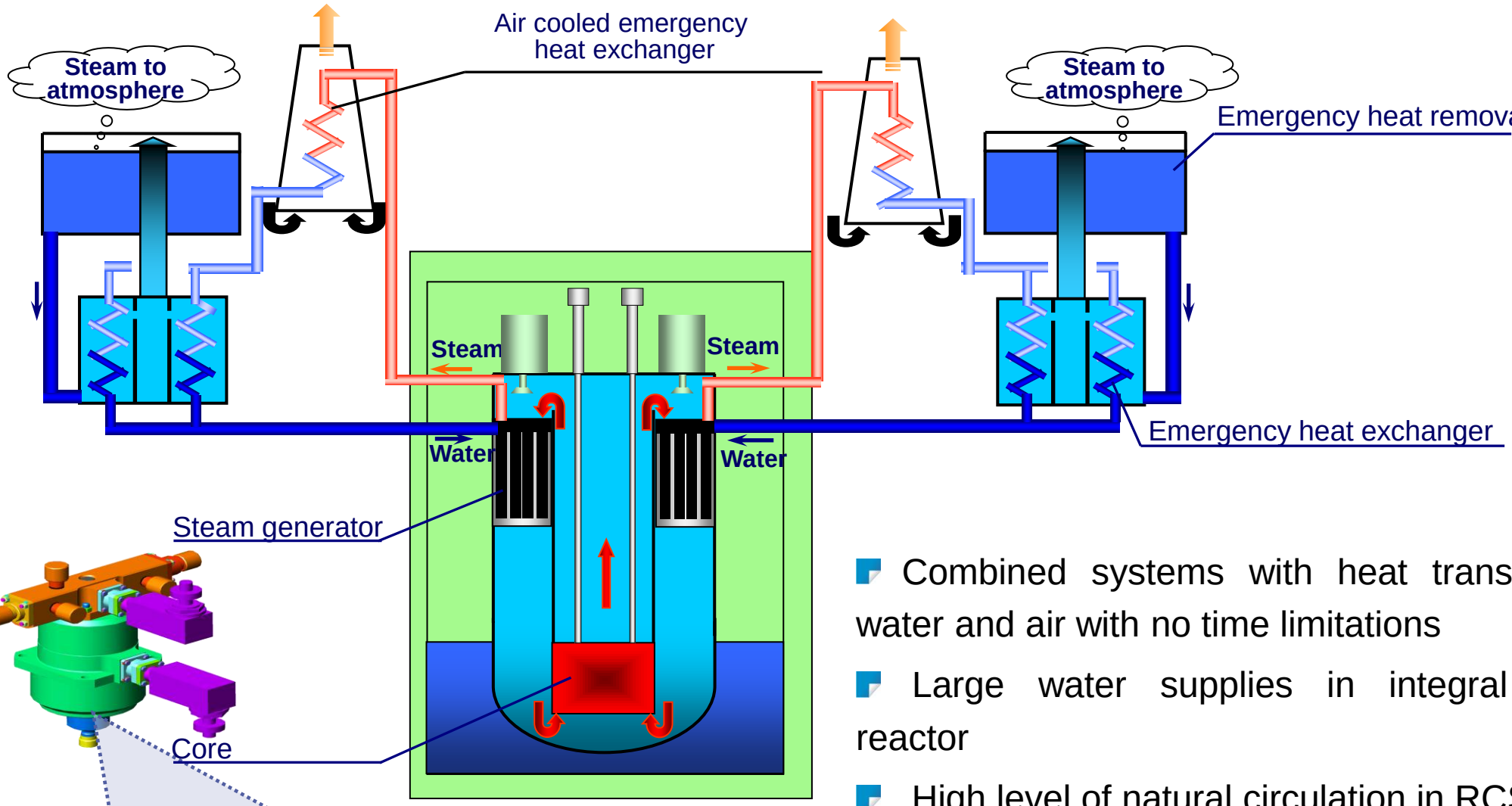
In case of emergency reactor shutdown system failures safety is provided in all modes by :

- Reactor inherent safety features
- Usage of frontline safety systems and self-actuating devices
- Maintaining of primary circuit pressure within elastic region for RCS elements

Pressure-actuated electric circuit-breakers de-energize CRDMs (shutdown the reactor) on:

- High reactor coolant pressure
- High containment pressure

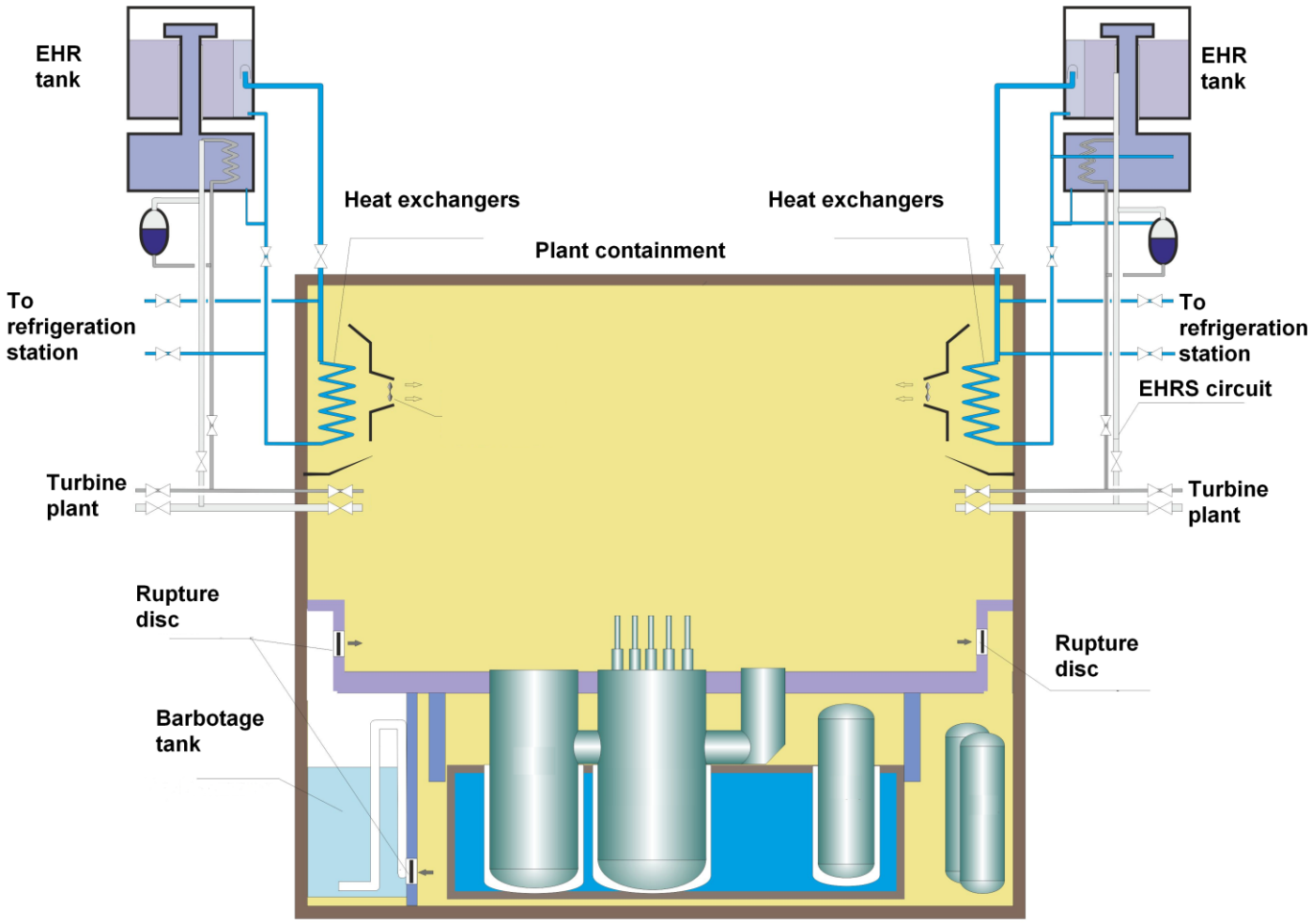
PASSIVE SAFETY SYSTEMS: Emergency heat removal system



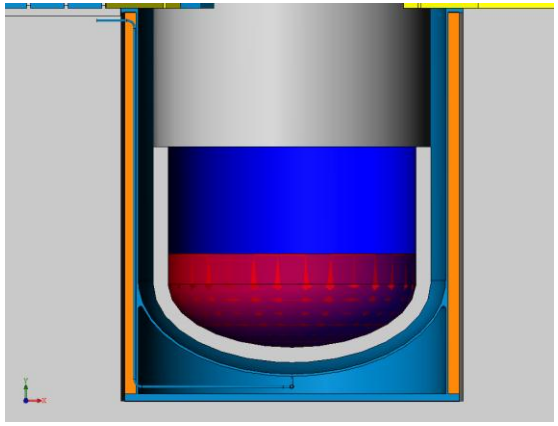
- Combined systems with heat transfer to water and air with no time limitations
- Large water supplies in integral type reactor
- High level of natural circulation in RCS

Hydraulically operated air distributors
Pneumatically-driven valves in the passive EHRS channels are opened on primary circuit overpressure

- The safety function is to protect the safety barrier (plant containment)
- In case of LOCA safety features provide that the core will be covered by the coolant
- Safety systems provide continuous emergency cooling of the core on account of containment designed for high inner pressure and heat removal by passive EHRS



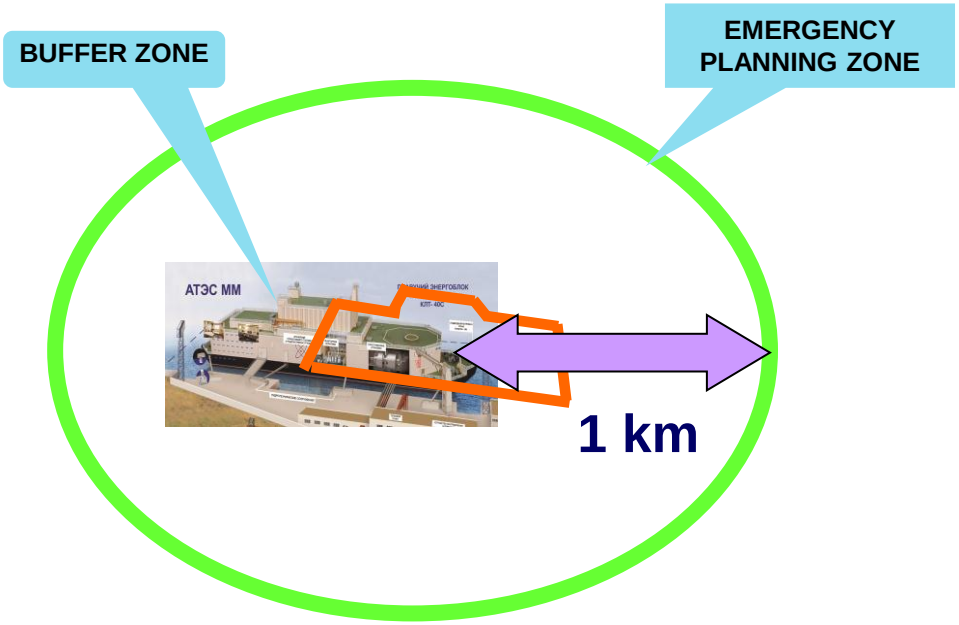
SEVERE ACCIDENT ANALYSIS



- The inner surface of the reactor vessel doesn't melt
- Heat is reliably removed from the outer surface of the reactor vessel bottom
- Mechanical properties of the reactor vessel material are preserved at the level that is sufficient to ensure the load bearing capacity

RADIATION SAFETY

CHARACTERISTIC	VALUE
1. Buffer zone size	**Coincides with NPP site boundary**
2. Emergency planning zone radius	**<1 км**
3. Emergency planning zone for mandatory population evacuation	**no zone**



PSA LEVEL 1 RESULTS

Scope of PSA	Core damage frequency (1/reactor·year)
Internal initiating events for full power	$<10^{-7}$
Low power and shutdown modes	$\sim 3 \cdot 10^{-9}$

Probabilistic safety analysis level 1 results indicated that KLT-40S floating power unit design is well-balanced and its safety level meets Russian regulatory requirements and IAEA recommendations for existing and future power plants

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THANK YOU FOR ATTENTION!