International Conference on Fast Reactors and Related Fuel Cycles: Challenges and Opportunities

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SVBR-100 Module-Type Reactor of the IV Generation for Regional Power Industry

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THE NECESSITY TO DEVELOP LARGE-SCALE REGIONAL NUCLEAR POWER (NP)

- **Widespread implementation of nuclear power sources for heat-electric supplying the regions is one of the most important conditions for stable development.**
- **This will assure the following:**
  - ☛ **scale exclusion of fossil fuel and power-independence for the regions;**
  - ☛ **replacement of fossil fuel power-sources which have become obsolete and expired;**
  - ☛ **socially acceptable tariffs for power production for the population and industry.**

BASIC REQUIREMENTS TO THE REGIONAL POWER (1)

- The regional power is “large” power (for example, up to 70 % of general power production in Russia)
- Therefore, widespread implementation of nuclear power sources in the regional power will require a great amount of nuclear fuel. In conditions of limited natural uranium resources this will result in the necessity to develop such power based on fast reactors operating in a closed fuel cycle in a mode of self-providing.
- Close location of the NHPP to cities imposes the additional strict requirements to safety of reactor facilities regarding to inherent self-protection properties and maximal deterministic elimination of the design basis accidents and severe accidents which are beyond the design basis.

BASIC REQUIREMENTS TO THE REGIONAL POWER (2)

- **Due to the large number of power-units required for regional power-supply, quantity production of the RFs will be required, and for their manufacture the necessity to use the unique equipment must be eliminated to the maximal possible extent, i.e. there must be opportunities for manufacturing the RFs at many engineering factories and at the same time do not hamper development of large-scale nuclear power (high-pressure vessels).**

BASIC REQUIREMENTS TO THE REGIONAL POWER (3)

- Scale development of regional power means that nuclear power-units will changeover from the unique class to a class of generally used industrial objects. From that viewpoint, RF operating must be maximally simplified regarding the requirements to the operational personnel's qualification, and that must be also assured by a high level of self-protection and passive safety properties of the RF.

BASIC REQUIREMENTS TO THE REGIONAL POWER (4)

- Due to different demands of regional users in power (100 – 600 MWe), a modular structure of the plant is preferable, which allows any power that is divisible by power of a single module 100 MWe and, therefore, assures elimination of multi-type designs of the RFs.
- Capacity of the standby power supply systems must be minimized that may be also assured by the modular structure of the NHPP based on small-sized modules.

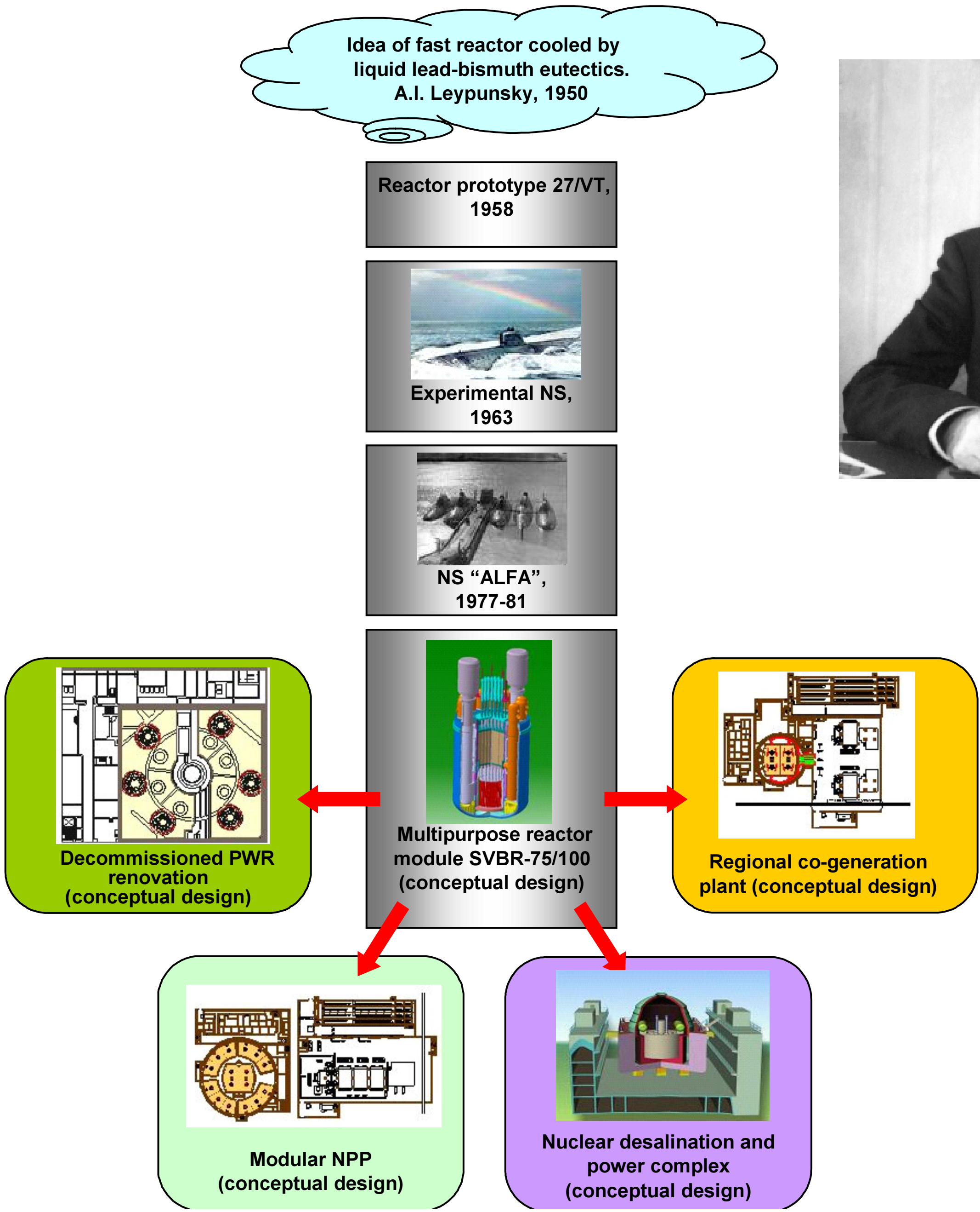
BASIC REQUIREMENTS TO THE REGIONAL POWER (5)

- With a purpose to minimize power losses caused by high extension of heating mains in certain cities, allocation of nuclear power sources over the user's territory may be required. And this also results in preference of the modules based on small-sized RFs (~100 MWe).
- The economic efficiency requirements result in the necessity to shorten maximally the schedule of plant construction that is possible to assure, for example, by expanding the factory manufacture of the RFs with railway transportation of ready units to the construction site while the scope of works on the site is minimized.

BASIC REQUIREMENTS TO THE REGIONAL POWER (6)

- Construction and operation of the entirely referent experimental-industrial power-unit must precede commercialization of the regional power NHPP for the purpose to verify technical and economical characteristics and operating qualities of the RF. This will make possible minimization of the investment risks in order to attract the private capital.
- It is the innovative nuclear technology of small-sized modular fast reactors with lead-bismuth coolant – SVBR-100 (Lead-Bismuth Fast Reactor of 100 MWe equivalent power) – that meets the totality of the highlighted requirements to the maximal extent.
- RF SVBR-100 is a two-circuit monoblock type facility that generates superheated steam.

Genesis of lead-bismuth cooled reactors



IMPORTANT FEATURES OF THE SVBR-100 TECHNOLOGY

The technology has been mastered for NS reactors in Russia.

Altogether 8 NSs with LBC cooled RFs were built including 7 NSs of class "Alpha" (in terms of NATO).

Due to its speed and maneuvering parameters this NS was entered into Guinness Book of Records.

THE BASIC PROBLEMS SOLVED WHILE MASTERING THE LBC COOLED NS RFs

- **In the course of designing and operating the LBC cooled reactor facilities (RF) at the NSs a package of the principal scientific and engineering problems on mastering the LBC technologies was solved:**

  - ☛ ***assuring the corrosion resistance of structural materials, controlling the LBC quality, and controlling the mass-transfer processes in the reactor circuit***
  - ☛ ***assuring the radiation safety of the personnel while carrying out works with the equipment contaminated with polonium-210 radionuclide***
  - ☛ ***multiple LBC “freezing-unfreezing” in the RF***

BASIC TECHNICAL CHARACTERISTICS OF RF SVBR-100

(basic variant : UO_2 fuel, overheated steam)

Parameter	Value
RF thermal capacity, MW	280
RF electric capacity (gross), MWe	106
Steam flow rate, t/h	580
Steam pressure/ temperature, MPa/°C	9.5 /400
LBC temperature, input / output, °C	345 / 495
Average power density of the core, kW/dm³	160
Average linear load on the fuel element, kW/m	26
Fuel: type U loading, kg U-235 average enrichment, %	UO_2 9016 16.5
Core lifetime, thousand full power hours	50
Interval between refueling, years	~ 8
RMB Dimensions: D×H (diameter × height), m	4.53 / 7.55
RMB weight without core and coolant, t	270

REACTOR SVBR-100 MEETS THE BASIC REQUIREMENTS TO THE IV-TH GENERATION REACTORS:

1. **EFFICIENT USE OF ENERGY POTENTIAL OF NATURAL URANIUM**

SVBR-100 reactor meets this requirement, because in the closed NFC when mixed oxide uranium-plutonium fuel is used it operates in a fuel self-sufficient mode, with core breeding ratio (CBR) being slightly more than 1.

2. PRINCIPALLY HIGHER LEVEL OF SAFETY

- **Reactor SVBR-100 meets this requirement owing to inherent self-protection and passive safety of the reactor, which have been assured by use of chemically inert lead-bismuth coolant (LBC) and integral arrangement of the primary circuit equipment in a single vessel operating at approximately atmospheric pressure.**

- **This enables:**

- to exclude many safety systems required for traditional type reactors with high value of potential energy stored in coolant, simplify and reduce the price of the NPP;

- to eliminate deterministically an opportunity of happening the severe accidents, which require population evacuation beyond the NPP site, caused not only by single accidental initial events but malevolent actions too;

- to locate the NPP within the city boundaries and use it as NHPP.

3. ENHANCED RESISTANCE TO NUCLEAR FISSILE MATERIALS PROLIFERATION

♦ **Reactor SVBR-100 meets this requirement owing to :**

- ☛ **use of uranium with enrichment below 20 % while using oxide uranium fuel at the first stage,**

- ☛ **extended core lifetime without refueling (7-8 years),**

- ☛ **elimination of technical opportunities for access to fuel during the lifetime,**

- ☛ **absence of breeding blankets, where weapon plutonium can be accumulated.**

4. ACCEPTABLE TECHNICAL AND ECONOMICAL PARAMETERS

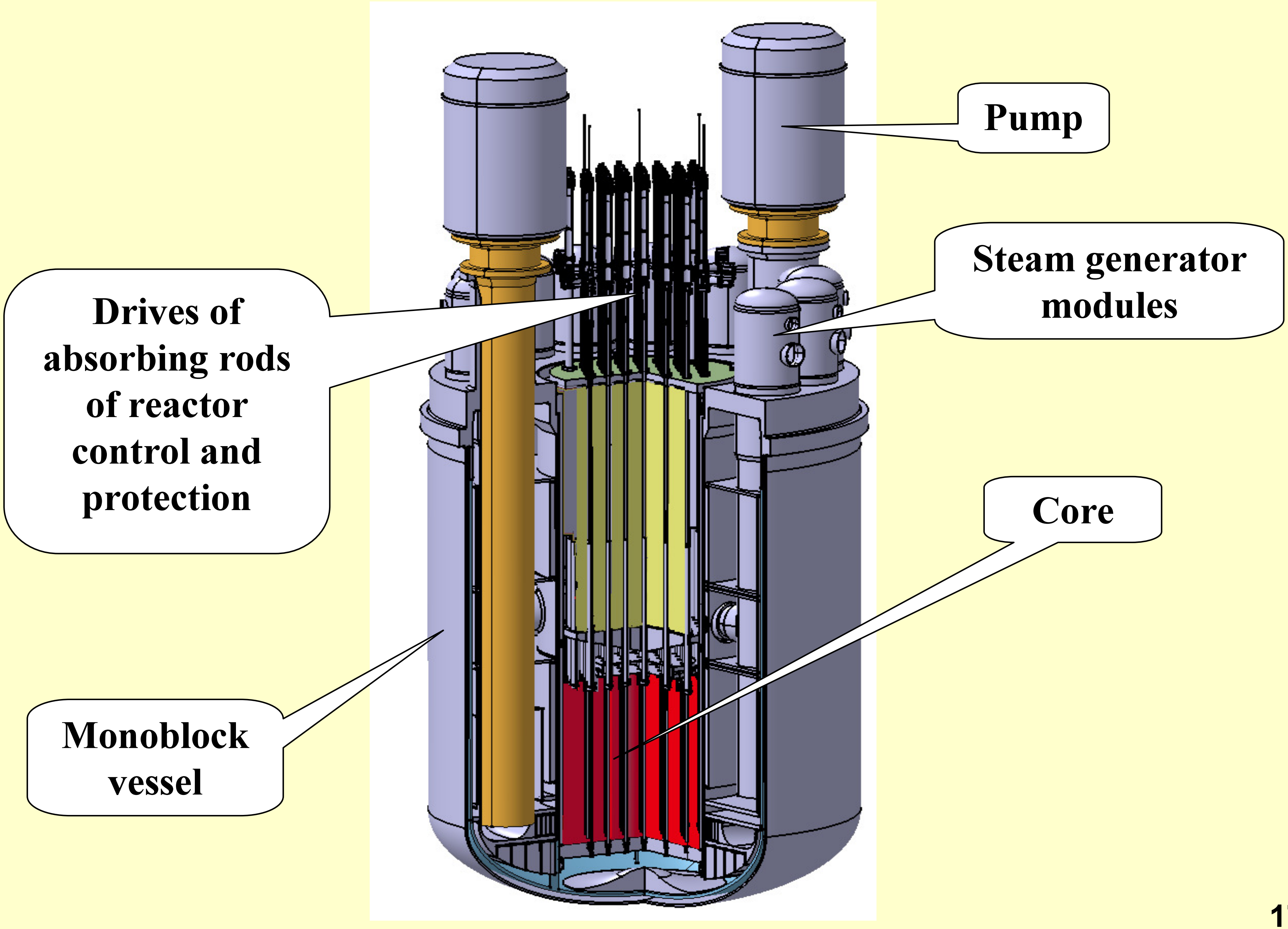
Reactor SVBR-100 meets this requirement owing to the following:

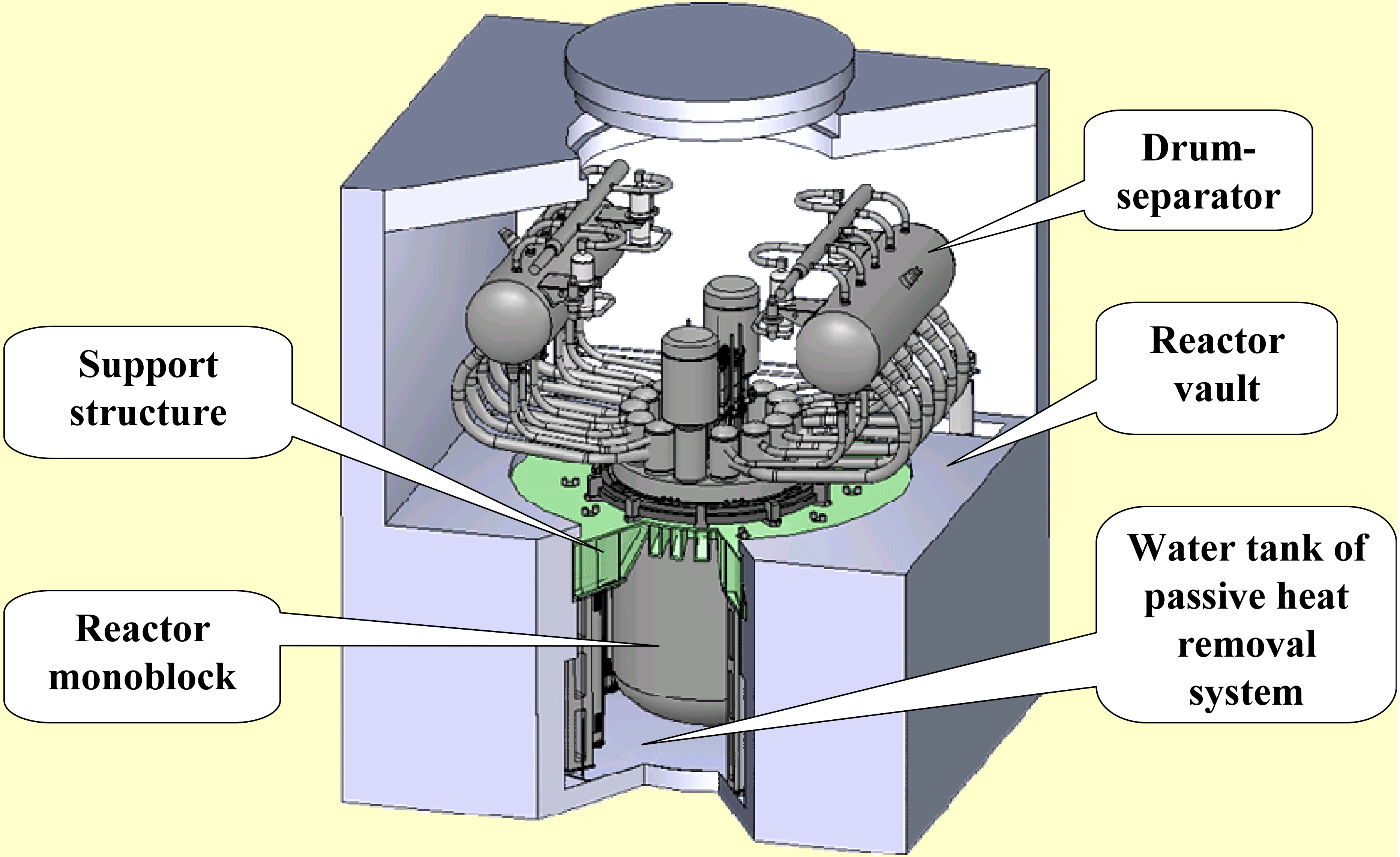
1) elimination of many safety systems required for traditional type reactors due to a high value of potential energy stored in the primary circuit coolant of such reactors,

2) high quantity production of manufacturing conditioned by small level of reactor capacity,

3) lack of the necessity to conduct R&D works and construct a demo prototype due to the fact that a well-tested unified reactor of 100 MWe is used in the NPP power-units of different capacity divisible by 100 MWe,

4) reduction of the investment cycle period.


Pump
Steam generator modules
Drives of absorbing rods of reactor control and protection
Core
Monoblock vessel


Drum-separator
Reactor vault
Support structure
Water tank of passive heat removal system
Reactor monoblock

SPECIFIC FEATURES OF SVBR-100 TECHNOLOGY

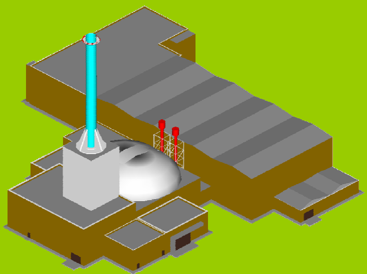
- ♦ The 100-600 MW nuclear power plants with such reactors can be sited at the energy-consuming centres in many regions Russia and some countries, which eliminates the expenses for construction of high-power electricity transmission lines;
- ♦ Manufacture of reactor facilities SVBR-100 does not require the unique engineering equipment and can be performed at different engineering factories, at the same time it will not impede the production of high pressure vessels for LWR type reactors.
- ♦ While constructing the modular power-units of different capacity and purpose, it is possible to use flow-line organization of construction and assembly works, which considerably reduces the schedule terms and cost of construction that is especially important in market economy conditions.

PRINCIPLES OF SAFETY SYSTEMS' PASSIVE ACTUATION:

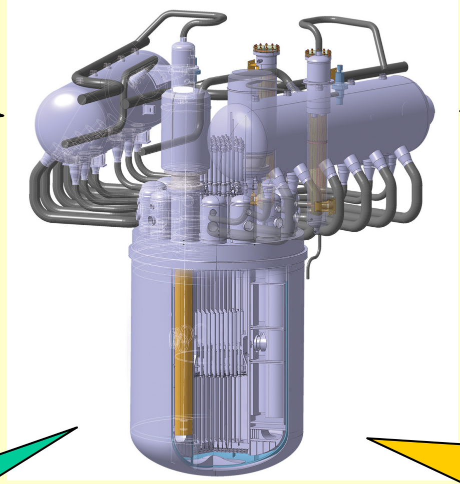
- Fusible locks of auxiliary safety rods to provide passive shutdown of the reactor in an event of coolant's overheating over 700 °C caused by damage of all servodrives of the basic emergency protection system under over-normative external impacts
- Bursting disk (membrane) to prevent over-pressurization of the reactor vessel that may be caused by steam pressure being over 1.0 MPa in an event of postulated large leak in the SG (simultaneously rupture of several tubes)
- Passive removal of residual heat in an event of blacking out the NPP and impossibility to remove heat via the SG is assured by transferring heat via walls of the monoblock vessel and protective casing to water: evaporation of water allows approximately a 4 days' grace period

MULTIPURPOSE USE OF RF SVBR-100

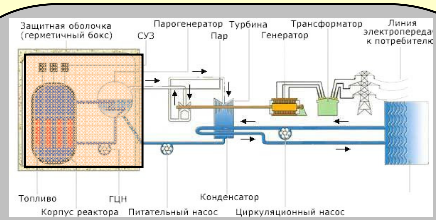
Modular NPPs and NHPPs located directly near cities



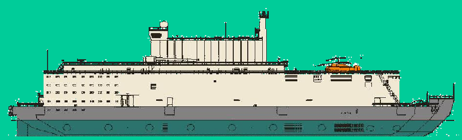
Reactor facility SVBR-100



Renovation of NPPs with LWRs withdrawn from operation



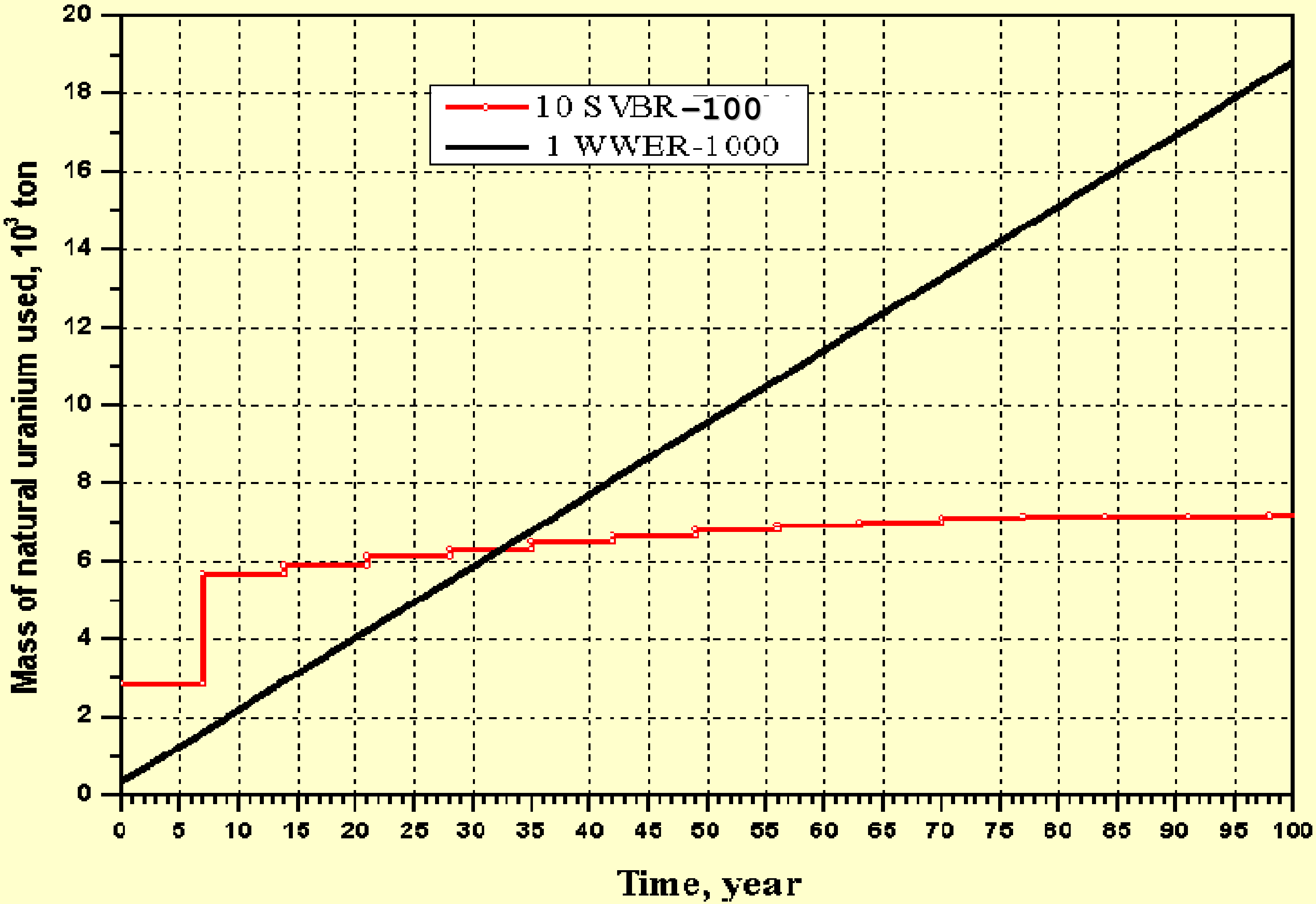
Floating NPPs for different purposes



Autonomous nuclear power-sources based on transportable reactor units

CAPABILITY OF THE REACTOR TO OPERATE USING DIFFERENT FUEL TYPES AND IN DIFFERENT FUEL CYCLES:

- **At the first stage: mastered uranium oxide fuel, CBR = 0,84, at postponed reprocessing:**
  - ☛ *minimum expenses for the fuel;*
- **MOX fuel, CBR ≥ 1 :**
  - ☛ *For UO_2 starting fuel load, closing of the fuel cycle can be realized in 15 years after two lifetimes. At this, the consumption of natural uranium during 60 years will be by 30 % less than its consumption by WWER reactors in terms of 1 GWe*
- **Nitride uranium and uranium-plutonium fuel :**
  - ☛ *improved safety and fuel cycle characteristics (the lifetime duration is 15 years)*



NATURAL URANIUM CONCUMPTION

CORE AND CORE ELEMENTS

Reactor operates without partial refuelings.

SNF is unloaded cassette-by-cassette.

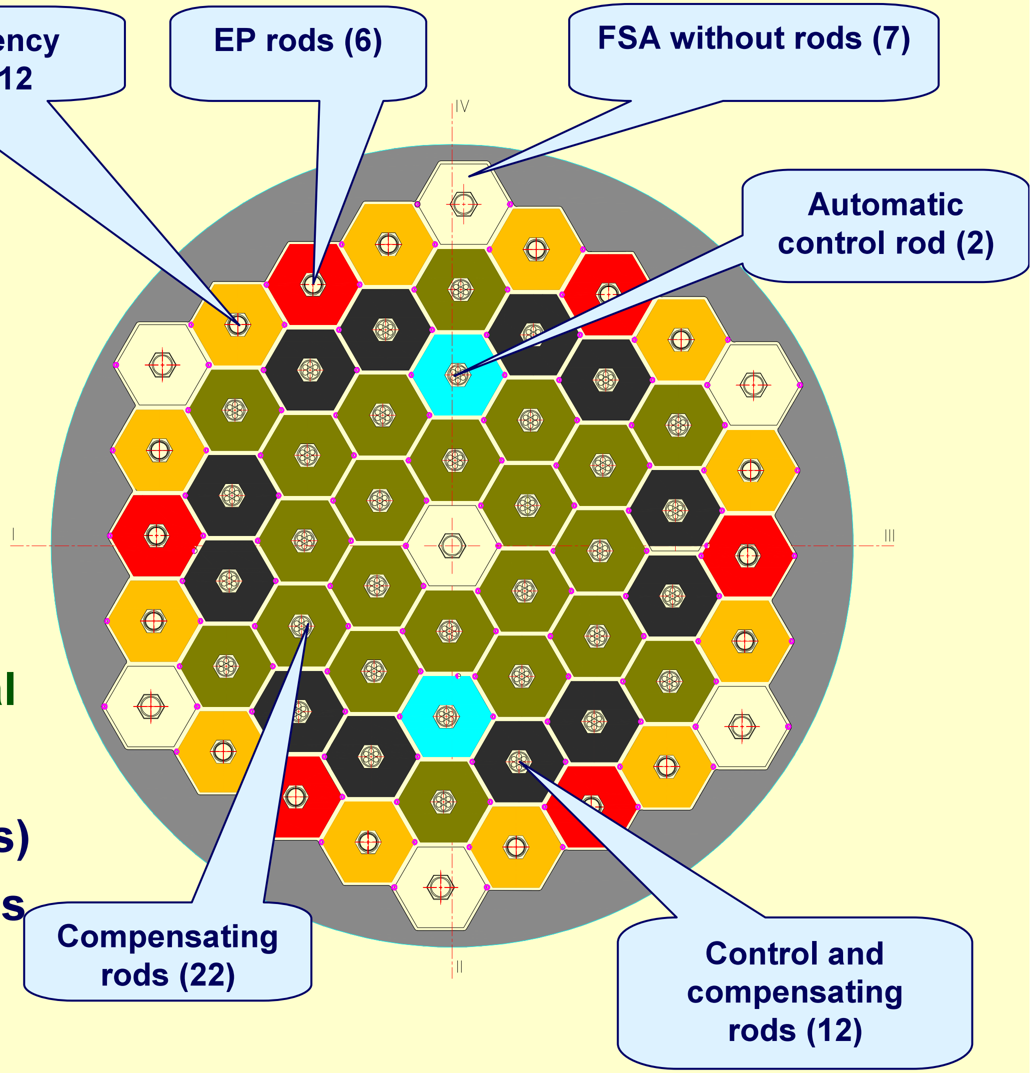
Fresh fuel is loaded as a single cartridge.

Fuel element is of a container type.

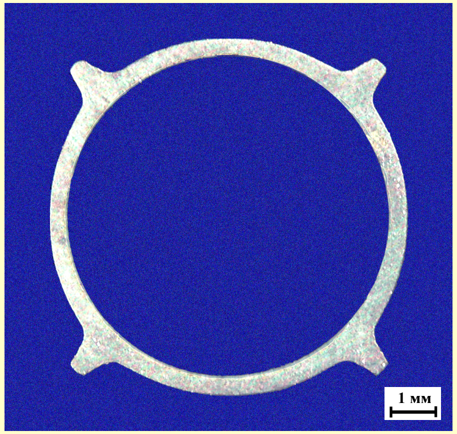
Wrappless FSA (total number is 61)

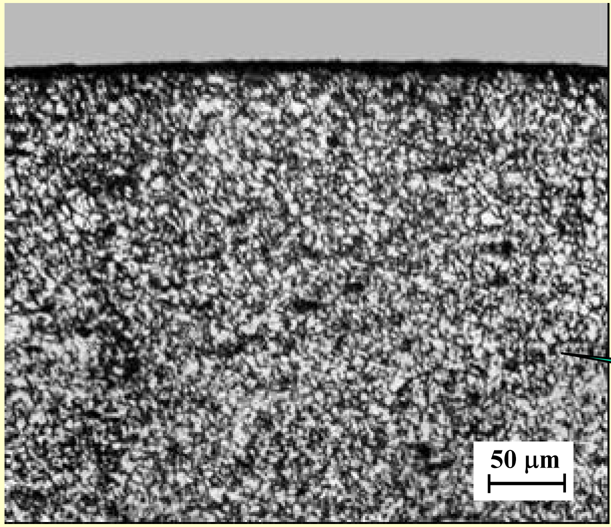
Boron carbide is an absorbing material in CPS rods (enrichment in ^{10}B - 50%)

Lowered power density (~ 2 times less) as compared with ship LBC cooled RFs



CORROSION RESISTANCE OF FUEL ELEMENTS CLADDINGS IN LBC





is verified by :

- testing at non-isothermal circulation facilities;
- testing in loops of MR and MIR reactors;
- the results of operating the fuel elements in the cores of LBC cooled NS RFs.

30`000 hours of testing in Pb-Bi at T=620ºC

CONCLUSION (1)

- For the SVBR-100 type RF the inherent self-protection properties assure deterministical elimination of the certain severe accidents, lack of the accidents, which are within the design basis, and elimination of the catastrophic consequences of the postulated accidents, which are beyond the design basis and require the population evacuation beyond the NPP site.

- It is viable that the high level of self-protection can be demonstrated without any financial and ecological damage in the controlled conditions when the tests for an experimental-industrial unit are performed.

CONCLUSION (2)

- ♦ Such level of inherent self-protection allows speaking of RF tolerance not only to the equipment failures and personnel's errors and their multiple superposition but to the malevolent actions as well, that assures high social acceptance of the SVBR technology. This allows a considerable reduction of engineering and financial risks, and enhancement of investment attractiveness of modular NPP SVBR-100.

- ♦ The properties and safety characteristics of the SVBR-100 type RF are obtained virtually "free of charge" only due to use of the fast neutron reactor, heavy liquid-metal coolant and integral design of the primary circuit

CONCLUSION (3)

- ♦ RF SVBR-100 meets the most important requirements to the reactor systems of the IV-th Generation, International Project INPRO and New technological platform for long-term perspective development of nuclear power in Russia.

- ♦ All these will allow economically effective application of those RFs at different power and purpose NPPs, which are located directly nearby the centers of population, as regional sources of electricity and heat, and for water desalination

CONCLUSION (4)

- ♦ Rosatom Scientific and Technical Council held on 15.06.06 approved development of the technical design of experimental-industrial power-unit based on RF SVBR-75/100.

- ♦ Realization of the Project an experimental-industrial power-unit based on RF SVBR-100 provide for Federal Target Programme "New Generation Nuclear Power Technologies for 2010 – 2015 Years and Future Trends up to 2020". There was made a decision on establishing a joint enterprise within the frameworks of state and private partnership of State Corporation "Rosatom" and private company "EuroSibEnergo".

THANK YOU VERY MUCH

FOR YOUR ATTENTION