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SVBR-TYPE REACTORS WITHOUT ON-SITE REFUELING CONCEPT DEVELOPMENT AND SCALING FACTORS IN SAFETY

FLOATING NPP CONCEPT ON THE BASIS OF LEAD_BISMUTH COOLED REACTOR SVBR-10

(Year report)

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INTRODUCTION

Traditional way of small power Nuclear Power Plants (NPP) construction may collide with a number of difficulties in the removed regions or developing countries even if it is supposed to use reactor technology without onsite refueling. It is necessary to create construction base, to deliver the equipment and materials, to provide the maintenance of a social infrastructure for the period of construction and operation. The optimum solution in this case may be in the way of ready for operation power unit shipment which does not leave on the site any radioactive materials after plant decommissioning. It may be considered alternate ways of the specified solution realization: floating NPP, coastal NPP, ground transportable NPP.

The coastal plant modification may be preferable for the Customer having or intended to develop own industrial - construction and social infrastructure. Otherwise for the Customer, apparently, there will be more preferable floating modification of NPP.

Among innovative technologies the technology based on application of modular multi-purpose fast reactors with Lead-Bismuth Coolant (LBC) is well prepared for accelerated introduction and fit to modern safety and proliferation resistance requirements. This technology is mastered in Russia with reference to reactors of nuclear submarines (NS). On its basis preliminary design of the multi-purpose SVBR-10 (by thermal capacity 43,3 MW) reactor facilities was been developed.

Initially SVBR-10 reactor [1,2] was developed as the basic part of transportable reactor unit (TRU) - functionally ready to application, completely factory manufactured and delivered to a NPP site (or taken out from NPP site) by water or heavy track way. Transportable reactor units with SVBR-10 can be applied in power units of nuclear power plants of low power for multiple purpose, such as electricity production, heat supply or sea water desalination. Depending on required capacity of the nuclear power plant, in its structure can be used single TRU, as well as several TRU joint at the NPP site into modular nuclear power steam generating facilities.

« The nuclear island » of NPP is formed on the basis of transportable reactor units with SVBR-10, delivered on NPP site by sea or waterway. Structure of NPP includes constructions and replaced TRU with SVBR-10. Constructions of NPP are the property of the country - user (Customer). Transportable reactor units are similar to charged « nuclear batteries » and are delivered by a principle «Build — Own — Transfer in rent ». It means, that the Supplier transfers to the Customer replaceable TRU in rent for the time determined by the core lifetime and time for reactor cooling before freezing (~20 years). In NPP site one or the several TRU are simultaneously maintained.

After connection of the new one, used TRU with the wasted core is decommissioned from operation and is transferred into cooling mode up to primary coolant freezing. Reactor module has no refueling operations at the NPP site.

After coolant freezing TRU is transported to the country - supplier for the core refueling, necessary repair work and replacements of the equipment with limited life-time. The released place on site is used for mounting of next TRU.

In 2006 “GIDROPRESS” together with Joint-stock Company “Atomenergo” and IPPE developed and investigated floating modification of NPP on the basis of SVBR-10 reactor module.

Results of study specify an opportunity of power source development with potentially higher level of safety and the best economic efficiency, than another types of reactors. In our opinion, such power sources can find wide application, in Russia, as well as in abroad countries, taking into account:

- The advanced properties of inherent safety based on passive principles;
- Super long core lifetime;
- Off-site refueling, that provides nuclear materials proliferation resistance;
- Safe transportations of reactors with "frozen" coolant;
- No needs in specialized infrastructure at NPP site.

In the present report the basic design provisions of Floating Nuclear Power Plant (FNPP) on the basis of SVBR-10 TRU, and also results of its economic efficiency estimations are presented.

2 BASIC DESIGN PROVISIONS OF FLOATING NPP WITH SVBR-10 REACTOR

Limited draft floating nuclear power station with 12 MW(e) capacity and up to 50 Gcal/hour cogeneration heat is intended for the electric power and a heat supply of settlements and the industrial enterprises located in coastal areas.

NPP operation is possible both in an independent mode, and in local electric grids structure together with others power-supplies.

The general concept of FNPP use includes:

- FNPP construction at the ship-building enterprise, coming to the end with acceptance tests and acceptance by the customer;
- FNPP transportation to a place of operation and disbracing it with use of the prepared waterside structures;
- Construction of the coastal infrastruc ture providing an opportunity of FNPP connection to coastal power grid;
- Operation of FNPP;
- Repair works and refueling are supposed on the specialized ship-repair enterprise.

Fast neutron reactor use with extra long core lifetime in FNPP structure allows to refuse carrying out on a place of operations with nuclear fuel, that allows to exclude from FNPP structure the refueling equipment and fuel storage and, hence, to reduce the sizes and weight of FNPP.

Navigability and strength characteristics provide FNPP towage by the sea and the necessary towing device is foreseen.

Stability and flooding resistance meet the requirements of the Russian Sea Register Rules of Navigation for nuclear ships (further NS).

FNPP provides long and reliable work under following conditions:

- Wind loadings up to 40 m/s;
- Careen - 5 ° and a trim - 1,5 °;
- Height of waves up to 1,5 m.

Architectural type of FNPP - non-self-propelled stake type vessel with a double bottom and double boards with the superstructure well developed for accommodation of power equipment.

Main dimensions and the shape of the hull:

- Length between perpendiculars - 93,3 m
- Width - 21,6 m

- Height of a board - 10,3 m
- Draft of vessel at transportation - 3,7 m
- Draft in working mode - about 4,2 m
- Displacement of a vessel (density of 1025 kg /m^3):
  - Empty - 6750 t
  - Displacement full - about 8000 t

3. POWER INSTALLATION

3.1. A general part

The main energy sources on FNPP are two reactor facilities SVBR-10. Parameters generated steam:

P = 4,2 MPa,

T = 410 °C.

FNPP can be operated in two modes: electricity production, electricity and thermal energy production:

- The maximal capacity of electric energy
  (without central heating) - 24 MW;
- Cogeneration mode:
  - Electric capacity - 12 MW;
  - Thermal capacity - 50 Gcal/hour.

Depending on conditions of operation and customer requirements FNPP can produce electricity and thermal energy in various ratios, fresh water and steam also can be produced. Configuration of power plant and auxiliary equipment set will vary depending on ratio between mentioned above services in energy and/or water supply.

The station is equipped with two auxiliary boilers 9 MW thermal capacity each, which are the reserve energy sources during transportation, start-up, submission of the electric power during scheduled services and equipment repairs.

3.2. The basic characteristics of power installation

The main power facilities compartments are:

- Reactor compartment;
- Compartment of main turbo-generators
- Boiler branch;
- Compartment of heaters for network water.

The general view of equipment placing is resulted in figure 1.

The structure of FNPP includes the following equipment:

- Two reactor facilities CVBR-10;
- Two turbo-generators;
- Auxiliary steam generating facilities consisting from two horizontal water-tube boilers (P = 3,1 MPa) with thermal capacity 9 MW each;
- The reserve diesel - generator 540 kW capacity;
- Two emergency diesel - generators 200 kW capacity each;
- Two desalination installations with productivity ~20,0 t/day;
- Auxiliary mechanisms and heat exchange equipment serving power installation;
- Steam heaters of network water;
- Water-water heaters of network water.

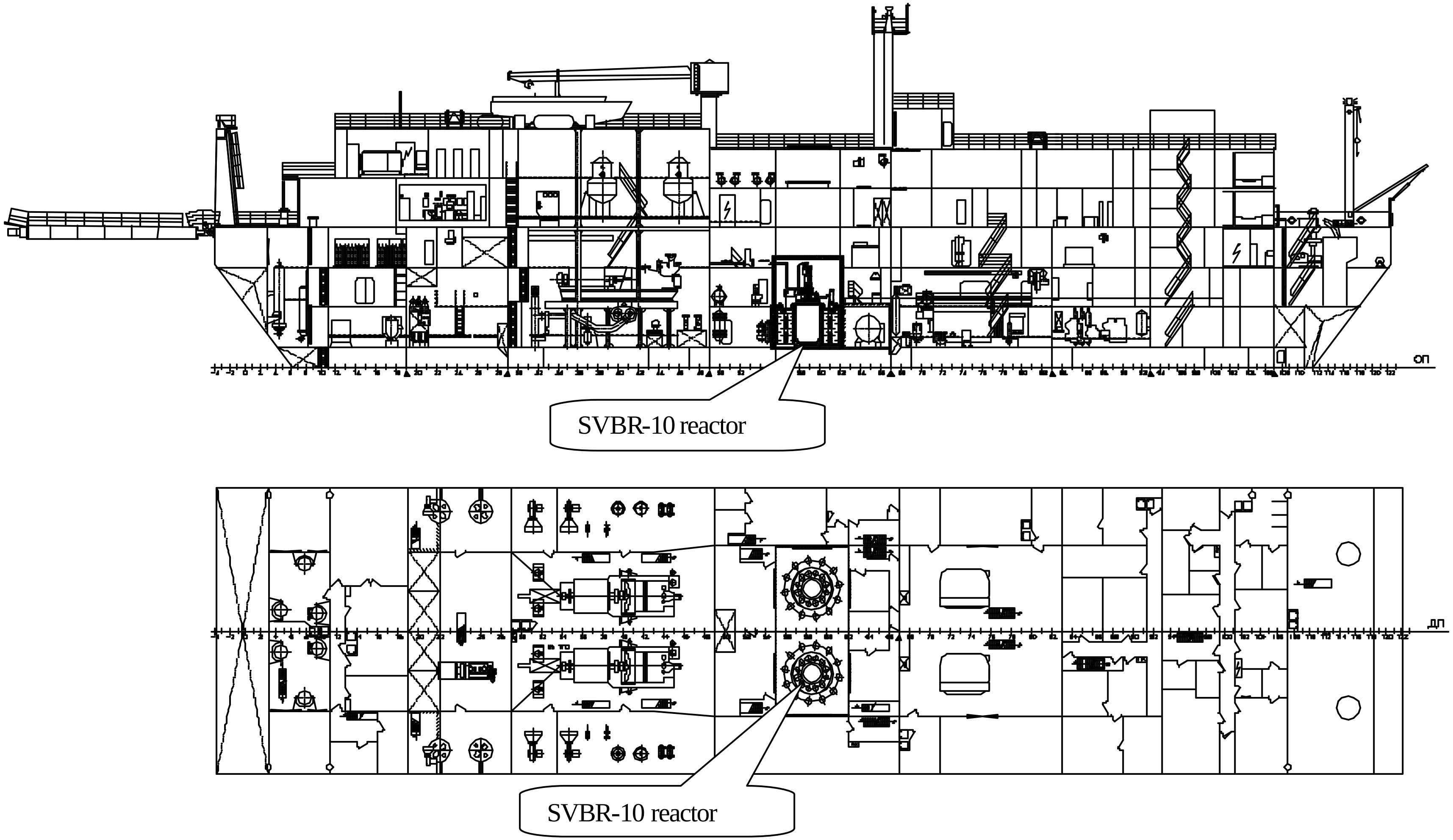

Figure 1 – Placing of equipment on FNPP with SVBR-10

3.3. Steam generating facilities

The main characteristics of SVBR-10 reactor facilities are resulted in table 1.

Table 1-The main characteristics of SVBR-10.

Title	Value
Thermal capacity of a reactor, MW	43,3
Steam output, t/hour	56
Parameters of generated steam: - Pressure, MPa - Temperature, ^{O}C	 4,2 410
Fuel: -Type - Average enrichment of fuel on U-235, at. %	 UO_2 18,4
Core lifetime , eff. hours	135 000
Time between refueling, years	~20
Design service life of the irreplaceable equipment, years	60

The following conservative principles are put in a basis of SVBR-10 design:

- Maximum application of the design solutions which have been checked up by operating experience;
- Use of the mastered regime parameters on the primary and secondary circuits;
- Orientation on existing fuel infrastructure and technological opportunities of the machine-building enterprises.

The following design solutions were selected in SVBR-10:

- ?The reactor on fast neutrons with chemically inert LBC and integrated configuration of the primary circuit at which the core, the equipment of the primary circuit and modules of steam generator are placed in the common vessel, thus the primary circuit has no pipelines and valves;

- Reactor vessel has safety casing and is placed into water tank of passive heat removal system which is formed by containment structure in the case of the floating power unit;
- The two-circuit heat removal system and a steam generator with repeated natural circulation are applied;
- Equipment placement and heat removal circuits arrangement ensure natural circulation level, sufficient for reactor cooling down without dangerous overheating of the core;
- The basic reactor components as well as steam generating installation components are executed as separate modules, thus the opportunity of their replacement and repair is provided;
- The core design supposes simultaneous refueling as a uniform cartridge (a new core). Refueling operations are made only on the factory - builder (once per 15-20 years);
- All equipment is located inside the sealed containment preventing leaks of radioactivity at emergency unsealing of reactor safety barriers. The protective containment is realized from tight flat sections. Application of flat designs equally resisting both to internal, and external pressure, allows to provide most rationally all requirements to this protective barrier in conditions of a floating construction. The protective containment is designed for static durability at overpressure up to 0,1 MPa, and also on the dynamic loadings arising at influence of man-caused and natural factors. Containment durability is sufficient for keeping of tightness at failures with FNPP flooding.

3.4. Steam-turbine plant (STP)

Rather simple circuit layout with feedwater heating only in deaerator has been chosen for maintenance of reliability. Waste steam after turbine drive of feedwater pumps is used for feedwater heating in deaerator. Steam extraction from low pressure turbine stages is used for heating up of auxiliary grid water.

The STP includes the following equipment:

- Two turbogenerators 12 MW capacity each;
- Two main condensers;

- Ejectors;
- Throttling -moistening devices;
- Barring gear and other equipment.

Each turbogenerator with serving mechanisms and devices works irrespective of devices and mechanisms of other board.

4. ECONOMIC EFFICIENCY OF THE PROJECT

The estimation of efficiency is based on calculation of the monetary streams generated by the investment project. For calculation of monetary streams the special computer model is used.

Estimation of projected economic efficiency was made under conditions of Kamchatka region according to heat and electricity prices on the date 01.01.2006.

Table 2 - Integrated parameters of efficiency

Title	Value
Simple pay-back period, years	10
Discounted pay-back period (discount rate -8 %), years	16
Internal yield	10,5%
Yield index	1,23

5. CONCLUSION

Conceptual project of floating NPP with two SVBR-10 reactors is developed according to innovative concept of reactors without onsite refueling and extra long core life time. Floating NPP with the simple pay-back period of 10 years may be attractive for investments.

REFERENCES

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