XA9744086

THE WATER DESALINATION COMPLEX BASED ON ABV-TYPE REACTOR PLANT

Yu.K. PANOV, Yu.P. FADEEV
OKB Mechanical Engineering

V.M. VOROBIEV
CKB "Baltsudproekt"

Yu.D. BARANAEV
Institute of Physics and Power Engineering

Russian Federation

Abstract

A floating nuclear desalination complex with two barges, one for ABV type reactor plant, with twin reactor 2 × 6 MW(e), and one for reverse osmosis desalination plant, was described. The principal specifications of the ABV type reactor plant and desalination barge were given. The ABV type reactor has a traditional two-circuit layout using an integral type reactor vessel with all mode natural convection of primary coolant. The desalted water cost was estimated to be around US $0.86 per cubic meter. R&D work has been performed and preparations for commercial production are under way.

1. GENERAL CHARACTERISTIC OF THE COMPLEX

The floating nuclear desalination complex is intended for desalination of seawater with total dissolved solids (TDS) content up to 41 g/l. The desalinated product water has a salt content of 500 mg/l (consistent with international standards for desalinated water). Nominal capacity of the complex is 40 000 m^3/day.

The complex comprises two barges:

- The 12 MW(e) "Volnolom"-type floating nuclear power station (FNPS) with an ABV reactor plant (RP);
- The desalination barge for seawater desalination by reverse osmosis.

This arrangement of the complex allows:

- Providing a possibility for separate application - the FNPS may be used for electricity and heat supply to industrial enterprises and villages in remote regions, and the desalination barge might be included, where economically expedient, in complexes with conventional power sources;
- Softening the requirements for the rigging of building enterprises and for dimensions and depths of the installation site due to reduction of the ship dimensions and displacement;
- Involving ship-building enterprises not specialized in nuclear ship building for fabrication of the desalination barge.

These factors provide an opportunity to increase the economic efficiency of the complex, including increasing the serial production volume.

Crew number:

- FNPS — 54 men
- Desalination barge — 21 men

The institutions responsible for development of the complex are CPB "Baltsudproect", St. Petersburg, the designer-general of the complex and OKB Mechanical Engineering, N. Novgorod, the designer-general of the reactor plant.

The complex should be installed with consideration of a particular site for its arrangement. Installation is possible either within naturally protected areas (fjords, bays, lagoons), or using man-made protective structures. Depths in the complex installation area should be not less than 5.4 m at the time of the ebb. The plant supporting system insures normal operation of the equipment under conditions of up to sea state 3 and wind velocity up to 40 m/s. The complex is installed on "mooring posts" using PMK-type wharves and "dead anchors".

Plant installation in areas where wind velocity does not exceed 25 m/s is possible with application of either standard anchors or using conventional mooring to a floating wharf. Final selection of the supporting scheme should be made according to the specific conditions of its arrangement. All ship-building components of the complex, strength characteristics, stability and floodability are consistent with the Russian Register Rules for sea-going ships.

2. "VOLNOLOM" FNPS WITH ABV REACTOR PLANT

The "Volnolom" FNPS with ABV reactor plant is intended for electricity, steam and heat supply to consumers, including operation as a part of seawater desalination complexes. They are economical and environmentally pure power sources satisfying the requirements of advanced reactors with enhanced safety, and have no limitations on installation.

Main Dimensions of "Volnolom" FNPS

Maximum length, m	96.8
Weight, m	21.6
Board height, m	10.3
Draught, m	4.5
Displacement, t	8 700

The FNPS comprises two main 6 MW nuclear power units and two reserve 2.8 MW diesel generators to provide replacement power unit during refueling or repair. Fuel storage for diesel generators is adequate for 45 days of operation.

The reactor plant was designed in compliance with national standards documents, IAEA recommendations (NUSS, INSAG-3, INSAG-6 series) and experience gained from improved NPP designs.

The design uses proven design and technologies of both a ground-based and marine reactor plants, including initially those for KLT-40 plants, whose operability has been confirmed by many years of successful operating experience.

High technical and economic features and quality of the plant are insured by the equipment building-block design and by implementation of requirements for quality assurance during all phases of its lifetime.

Design decisions for ABV plants are coordinated with existing Russian manufacturing and technological capabilities, which allows supply to the customer of the entire set of equipment for the nuclear power plant with a guaranteed high quality of fabrication and delivery schedule.

The RP has a traditional two-circuit layout using an integral type reactor vessel with all mode natural convection of primary coolant.

Enhanced safety of the plant is provided by inherent self-protection, application of the defence-in-depth concept, usage of self actuating devices, availability of engineering safety features and considerable time reserve for corrective actions by personnel.

Principal Specifications of ABV RP Power Unit

Reactor thermal power, MW(th)	38
Nominal electrical power, MW(e)	6
Maximum capacity of heat supply, Gcal	12
Primary circuit parameters:	
- pressure, MPa	15.4
- core outlet temperature, °C	330
Core lifetime, hours	22 000
Steam parameters:	
- steam pressure, MPa	3.14
- steam temperature, °C	290
Greed water temperature, °C	
- direct	120
- return	70
Service life, years	
- up to yard repair	10
- total	30-50

The integral design of the reactor and the application of natural convection of the primary coolant allows considerable reduction in primary circuit volume, simplifies power supply and plant control and decreases power consumption for its own needs.

The reactor and primary equipment are encapsulated in a special containment, insuring localization of radioactive products during design basis and beyond design basis accidents. Dedicated structural protection is envisaged to prevent containment damage due to extreme external impacts.

The availability of safety barriers and confinement systems exclude, practically completely, radioactivity release beyond the plant confines during design basis accidents. During beyond design basis accidents with postulated core melting, radioactivity release is considerably below standards.

The "Volnolom" FNPS project was the winner at a competition "Small Nuclear Power Stations-91" held by the Russian Federation Nuclear Society.

Currently, preparations for construction of a pilot FNPS at JSC "Baltiyskiy Zavod", St. Petersburg, are underway. Construction time is 4 years.

3. DESALINATION BARGE

The desalination barge comprises: water intake system, water pretreatment system, high pressure pump house, seawater desalination units and the system for cleaning and regeneration of the desalinating units.

Water intake, depending on the conditions of a particular complex, may be accomplished by either direct water intake through the barge Kingston valves or by water intake through a special pipeline from a remote water intake unit installed at some distance from the complex.

Main Dimensions of the Desalination Barge

Maximum length, m	72
Width, m	24
Board height, m	10
Draught, m	3.9
Displacement, t	6 400

Water supply to the desalination complex may be carried out by pumps having 1000 m^3/hr capacity each through two independent lines. Each independent line carries the full capacity of water supply for desalination.

At the plant inlet source, seawater is filtered and subjected to chemical treatment. Multi-media filters (one-two-three-layer) with various filtering materials are the main means for source water purification from suspended materials.

Coagulant is usually introduced to the source water prior to the filters to increase purification efficiency (salts of Fl or Al usually). Pretreatment filters are filled with expanded clay aggregate, coal, and quartz sand. After passing through the filters water is subjected to chemical treatment. Final (finishing) purification will be performed by cartridge filters.

An $NHSO_3$ solution which suppresses biological growth on the desalination plant surfaces is introduced to the feedwater system prior to the cartridge filters to protect synthetic materials used in cartridge filters and reverse osmosis components against the action of oxidizers, particularly Na_4ClO.

To prevent creation of scaling on membrane surfaces, acids or anti-scaling inhibitors are added (hexametaphosphate, tripolyphosphate. polyacryl, etc.). Selection of the specific method of chemical treatment, providing the required quality of source water, may be made based on the results of specific examination for the installation site of the complex.

Seawater is supplied to the desalination system by high pressure pumps which take water from the purified water tank and supply it to the desalination units at 6.5 MPa pressure. The tank is provided with regenerative heating of the water up to about 60°C. The pumps operate with 4 independent desalination trains each comprising 9 desalination units. The number of pumps is 4 (including a reserve).

Pump drive is by electric motors and hydro-turbines (Pelton turbines).

High pressure pumps supply seawater, which has been subjected to pre-purification and chemical treatment, to desalination units arranged within the dimensions of an international standard sea container (6.0 m × 2.5 m × 2.6 m).

Each block comprises 150 filter modules. Blocks are combined into trains (nine desalination units each) according to the seawater supply and discharge.

Main Characteristics of Single Train

Number of modules	1 350
Number of units	9
Desalinated water output, m^3/hr	445
Seawater consumption, m^3/hr	1 200

The use of Permacep B-10 type membranes from DuPont is envisaged.

It is anticipated that membrane replacement will be performed every 3 years (3-5 years according to manufacturer's data). To prolong membrane lifetime, a system for periodical membrane cleaning with fresh water is provided. PO "Proletarsky Zavod", St. Petersburg, is the supplier of the desalination units.

4. TRANSPORTATION OF THE COMPLEX TO THE OPERATING SITE

The dimensions of the FNPS and the desalination barge allow them to be placed in the hold of the Danube Sea Steamship Line's "Boris Polevoy" heavy lift ship.

If required, of if the option for transportation by heavy lift ship is not acceptable, delivery of the complex by towing is possible and the complex is provided with all required equipment for this purpose. This transportation scheme is analogous to the towing of docks and crane barges.

5. ECONOMIC ASPECTS

The approximate price of the seawater desalination complex is US$ 93 million, consisting of US$ 70 million for the FNPS and US$ 23 million for the desalination barge.

The approximate specific operating costs amount to US $0.86/$m^3$.

Calculation of the floating equipment construction price was performed with regard to conditions at JSC "Baltiyskiy Zavod", St. Petersburg. Prices were determined on the basis of stock exchange prices with recalculation for the ruble exchange rate.

Preliminary data from equipment suppliers were taken into account for such main components as desalination units, Pelton turbines and high pressure pumps.

Costs for the coastal structures and installation of the complex were determined under conditions of installation in a protected area (wind not greater than 20-25 m/s), at depths allowing installation not more than 20-30 m from the coast, and for duration of transport in the hold of the "Boris Polevoy" not more than 20 days. Arrangement of a system comprising

2 pipelines is envisaged on the coast, at a distance up to 250 m. Storage tanks are not included in the price of coastal structures.

Annual expenditures on the crew are evaluated assuming use of a Russian crew and a cost per crew member of US$ 80/d. Annual costs for repair, supply and maintenance of the complex (excluding replacement of membrane components) were evaluated in percentage of the total price, and amount to approximately 4%.

Costs for replacement of membrane components during the service life of the complex (30 years) are determined assuming their replacement every 3 years.

Prices of chemicals for pretreatment of source water and final treatment of fresh water, as well as of those for membrane component cleaning, were determined by data from DuPont - an anticipated supplier of these chemicals.

Currently, due to increasing the reactor thermal power up to 60 MW, an option is being considered for replacement of the reserve Diesel generators by two additional turbo-generators, increasing the FNPS power up to 24 MW. This would allow production of more than 65 000 m^3/d of fresh water and reduce specific operating expenditures to US \$0.53/m^3.