HEAT AND POWER SOURCES
BASED ON NUCLEAR SHIPBUILDING
TECHNOLOGIES

Veshnyakov K.B., Fadeev Yu.P.
MAIN FIELDS OF OKBM ACTIVITY

1947 FOUNDATION OF THE ENTERPRISE

MARINE REACTOR PLANTS FOR THE NAVY

MARINE REACTOR PLANTS FOR THE CIVIL FLEET

HIGH-TEMPERATURE GAS-COOLED REACTORS

FAST REACTORS

NUCLEAR FUEL HANDLING EQUIPMENT

UNIFIED EQUIPMENT FOR NPP (PUMPS, FANS)
JSC “OKBM AFRIKANTOV” STRUCTURE

DESIGN DEVISION

- Development of plants and equipment of nuclear power complex

RESEARCH AND TESTING COMPLEX

- Scientific research and full-scale tests

PRODUCTION FACILITIES

- Fabrication of pilot equipment for nuclear power industry
SMALL NPP BASED ON NUCLEAR SHIPBUILDING TECHNOLOGIES

- APPLICATION OF PROVEN TECHNOLOGIES OF SHIP-BASED MODULAR REACTORS
  - OPERATION EXPERIENCE OF SHIP-BASED REACTORS OVER 6500 REACTOR/YEARS
  - LONG-TERM EXPERIENCE IN DESIGNING AND FABRICATION OF SHIP-BASED MODULAR REACTORS
  - APPLICATION OF PREVIOUS R&D RESULTS

- APPLICATION OF PWR REACTORS OPERATION TECHNOLOGY AND EXPERIENCE

- APPLICATION OF NPP OPERATION TECHNOLOGY AND EXPERIENCE FOR DISTRICT HEATING

- INTERNATIONAL REQUIREMENTS FOR SAFETY
APPLICATION OF SMALL NUCLEAR POWER SOURCES

FLOATING PLANTS FOR ELECTRICITY AND HEAT SUPPLY FOR HARD-TO-REACH COASTAL AREAS OR OIL AND GAS PRODUCTION

AUTONOMOUS POWER SUPPLY OF MARINE OIL-PRODUCING PLATFORMS

FLOATING NUCLEAR POWER-DESALINATION COMPLEXES

GROUND PLANTS FOR AUTONOMOUS POWER SUPPLY
REACTOR TYPES FOR NUCLEAR POWER SOURCES

ABV-6M
THERMAL POWER
16…54 MW
ELECTRICAL POWER
3.5…10 MW
COMPACT INTEGRAL REACTOR

KLT-40S
THERMAL POWER
150 MW
ELECTRICAL POWER
38.5 MW
COMMERCIAL MODULAR REACTOR FOR NUCLEAR ICE-BREAKERS AND SHIPS

RITM-200
THERMAL POWER
175 MW
ELECTRICAL POWER
~45 MW
COMPACT DESIGN
### MAIN CHARACTERISTICS OF FLOATING AND GROUND PLANTS

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>FLOATING CO-GENERATION PLANT</th>
<th>GROUND CO-GENERATION PLANT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABV-6M</td>
<td>KLT-40S</td>
</tr>
<tr>
<td>NUMBER OF RP</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>RP THERMAL POWER, MW</td>
<td>$2 \times 38$</td>
<td>$2 \times 150$</td>
</tr>
<tr>
<td>ELECTRICAL POWER IN CONDENSATION MODE, MW</td>
<td>$2 \times 8.6$</td>
<td>$2 \times 38.5$</td>
</tr>
<tr>
<td>ELECTRICAL POWER IN CO-GENERATION MODE, MW</td>
<td>$2 \times 6$</td>
<td>$2 \times 19.4$</td>
</tr>
<tr>
<td>HEAT SUPPLY, GCAL/H</td>
<td>$2 \times 12$</td>
<td>$2 \times 70$</td>
</tr>
<tr>
<td>REFUELING PERIODICITY, YEARS</td>
<td>once every ten years</td>
<td>once every three years</td>
</tr>
<tr>
<td>HOURS OF POWER OPERATION PER YEAR, H</td>
<td></td>
<td>7500…8000</td>
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</tbody>
</table>
FLOATING NPPs – A NEW GROUP OF POWER SOURCES

- **AUTONOMOUS POWER UNIT** is mounted on non-self-propelled barge or on pontoon system
- **COMPLETELY FABRICATED** at the shipbuilding yard
- **SUPPLIED TO THE CUSTOMER** on a turnkey basis after acceptance tests
- **TRANSPORTED TO THE SITE** by water
- **LONG-TERM OPERATION** without refueling or repair
- **TOTAL SERVICE LIFE** of the power unit is 40 years
- **POSSIBILITY OF CHANGING THE POWER UNIT** basing site
FLOATING NPP SAFETY UNDER EXTERNAL IMPACTS

- WATER AREA PROTECTION AGAINST UNAUTHORIZED ACCESS OF WATER VESSELS AND FLOATAGE
- PLANT FLOODABILITY IS PROVIDED BY DIVIDING THE HULL INTO WATER-PROOF COMPARTMENTS AND IS DEMONSTRATED AT FLOODING OF ANY TWO NEIGHBORING COMPARTMENTS. WHEN ANY TWO NEIGHBORING COMPARTMENTS ON ANY BOARD ARE FLOODED, THE MAXIMUM HEEL DOES NOT EXCEED 3%
- REACTOR PLANT PROTECTION AT FNPP COLLISION WITH OTHER VESSELS IS PROVIDED BY REACTOR ARRANGEMENT IN THE MIDSHIP BODY ABOVE DOUBLE BOTTOM
- MULTI-LAYER UPPER DECKING OF THE PLANT SUPPRESSES THE KINETIC ENERGY OF A FALLING AIRCRAFT OWING TO SPECIAL DESIGN MEANS DISTRIBUTING THE BLOW FORCE OVER A LARGER AREA
- FNPP IS MAINTAINED IN NORMAL CONDITIONS AT STORM-FORCE WIND OF 80 M/S
- SEISMIC STABILITY AND PROTECTION AGAINST STORM WAVES AND EARTHQUAKE WAVES ARE PROVIDED BY NATURAL OR ARTIFICIAL BARRIERS (ISLANDS, CAPES, BREAKWATERS) OR BY FNPP OFFSHORE ARRANGEMENT
LAYOUT OF MAIN KLT-40S RP EQUIPMENT

- TWO-LOOP PLANT WITH PRESSURIZED REACTOR WHICH IS CONNECTED BY THE COAXIAL NOZZLE SYSTEM TO COIL-TYPE STEAM GENERATORS (4 PCS) AND PRIMARY CIRCUIT CIRCULATION PUMPS (4 PCS)

- SUPPLY TO CONSUMERS
  - ELECTRIC POWER: 20…70 MW
  - HEAT: 50…140 GCal/h

- DESALINATION COMPLEX
  - NOMINAL OUTPUT FOR DESALINATED WATER, m³/day: 100000
  - POWER, MW(el): 2x35
KLT-40S REACTOR

◆ REACTOR TYPE
VESSEL-TYPE PRESSURIZED WATER

◆ THERMAL power, MW (t) 150

◆ FUEL TYPE
CORE, MEETING NON-PROLIFERATION REQUIREMENTS, DEVELOPED ON THE BASIS OF LONG-TERM OPERATION EXPERIENCE OF ICE-BREAKER CORES

◆ FUEL ENRICHMENT, % <20

◆ REFUELING CYCLE, YEARS 3

◆ SERVICE LIFE, YEARS 40

PRODUCTION TIME OF A COMMERCIAL FLOATING NUCLEAR CO-GENERATION PLANT – 2.5 YEARS

LENGTH, M: 140.0
WIDTH, M: 30.0
BOARD HEIGHT, M: 10.0
DRAUGHT, M: 5.6
DISPLACEMENT, T: 21 000

FLOATING NPP BASED ON KLT-40S POWER UNIT
SPENT FUEL HANDLING

Transportation of spent fuel from reactor to cooling tank
Transportation of fresh fuel cassette to reactor
Transportation of spent fuel from cooling tank into canisters of dry storage tank
RITM-200 STEAM GENERATING UNIT AND LAYOUT

**RP EQUIPMENT LAYOUT**

- **MASS OF RP IN CONTAINMENT** – 1100t
- **OVERALL DIMENSIONS (LxBxH)** – 6 x 6 x 15.5 m

**SG Unit**

- INTEGRAL PRESSURIZED WATER REACTOR WITH FORCED CIRCULATION OF PRIMARY COOLANT AND EXTERNAL GAS PRESSURIZATION SYSTEM FOR MULTI-PURPOSE ICE-BREAKERS

- **THERMAL POWER, MW** 175
- **FUEL ENRICHMENT, %** <20
- **REFUELING INTERVAL, years** 7
- **SERVICE LIFE, years** 40

**FINAL DESIGN OF THE ICE-BREAKER – 2009**

RP could be used also for stationary and floating power units
ABV-6M STEAM GENERATING UNIT AND REACTOR

- INTEGRAL PRESSURIZED WATER REACTOR WITH NATURAL CIRCULATION OF PRIMARY COOLANT AND EXTERNAL GAS PRESSURIZATION SYSTEM

- RP MAIN EQUIPMENT IS ARRANGED AS A SINGLE STEAM-GENERATING AGGREGATE ON METAL-WATER SHIELDING TANK

- THERMAL POWER, MW to 45
- FUEL TYPE, STANDARD FA OF KLT-40S CORE
- FUEL ENRICHMENT, % <20
- REFUELING INTERVAL, years 10
- SERVICE LIFE, years 60
ABV-6M REACTOR PLANT

COMPETITIVE ADVANTAGES

❖ INTEGRAL REACTOR WITH 100% NATURAL CIRCULATION OF COOLANT
❖ UNIFIED STEAM-GENERATING AGGREGATE FOR GROUND AND FLOATING NPP
❖ MINIMUM INTERFACES WITH SHIP SYSTEMS

❖ MASS OF STEAM-GENERATING AGGREGATE 200 t
❖ LENGTH 5 m
❖ WIDTH 3.6 m
❖ HEIGHT 4.5 m
### LIFE CYCLE

- **Manufacture and Tests** at the specialized factory
- **Transportation**
- **Operation without Refueling** on site
- **Transportation**
- **Repair and Refueling** at the specialized factory
- **Transportation**
- **Disposal of the Power Unit and RP**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Maximum Length, m</td>
<td>97…140</td>
</tr>
<tr>
<td>Width, m</td>
<td>16…21</td>
</tr>
<tr>
<td>Board Height, m</td>
<td>10</td>
</tr>
<tr>
<td>Draught, m</td>
<td>2.5…2.8</td>
</tr>
<tr>
<td>Displacement, t</td>
<td>from 8700</td>
</tr>
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</table>
MAIN BUILDING OF GROUND NPP WITH ABV-6M REACTOR

- LENGTH 67 m
- WIDTH 47 m
- HEIGHT 30 m

ALL MAIN BUILDING STRUCTURES ARE DESIGNED TO WITHSTAND LOADS ON BUILDINGS OF SEISMIC STABILITY CATEGORY I, WITH ACCOUNT OF AIRCRAFT CRASH, AIR SHOCK WAVE AND A MAGNITUDE 7 EARTHQUAKE

- MASS OF REACTOR MODULE 600 t
  - LENGTH 13 m
  - DIAMETER 8.5 m

- ABV-6M RP GROUND OPTION IS A STAND-ALONE, READY-TO-OPERATE MODULE
- THE MODULE PRESSURE VESSEL FUNCTIONS AS A CONTAINMENT

MODULE TRANSPORTATION TO CONSTRUCTION SITE
NUCLEAR POWER-TECHNOLOGICAL PLANT (ABV-6M)

GENERATION OF ELECTRIC POWER AND PROCESS HEAT FOR INDUSTRIAL ENTERPRISES AND HOUSING SETTLEMENTS

1 Reactor module
2 Process steam generators
3 Generator
4 Refueling machine
5 Cooling pool
### MAIN CHARACTERISTICS OF THE POWER-TECHNOLOGICAL NPP

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Number of ABV-6M reactor units</td>
<td>6</td>
</tr>
<tr>
<td>Number of process steam generators</td>
<td>6</td>
</tr>
<tr>
<td>Number of turbogenerators</td>
<td>2</td>
</tr>
<tr>
<td>Steam output, t/h</td>
<td>6 x 53</td>
</tr>
<tr>
<td>Steam for house loads, t/h</td>
<td>53</td>
</tr>
<tr>
<td>Secondary steam for customers, t/h</td>
<td>265</td>
</tr>
<tr>
<td>Electric power of turbogenerators, MW</td>
<td>2 x 4.25</td>
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<tr>
<td>Parameters of primary steam:</td>
<td></td>
</tr>
<tr>
<td>- pressure, MPa</td>
<td>3.2</td>
</tr>
<tr>
<td>- temperature, °C</td>
<td>290</td>
</tr>
<tr>
<td>Parameters of secondary steam for customers:</td>
<td></td>
</tr>
<tr>
<td>- pressure, MPa</td>
<td>3.0</td>
</tr>
<tr>
<td>- temperature, °C</td>
<td>260</td>
</tr>
</tbody>
</table>
The nuclear power plant is assembled of reactor modules (reactor plants in the containment). Modules with reactor plants are supplied by the manufacturer on a turn-key basis.

**First category of seismic stability**

**AIRCRAFT CRASH:**
- MASS, T
- VELOCITY, M/S

**AIR SHOCK WAVE:**
- BLAST PRESSURE, KPA
- DURATION, S

**EARTHQUAKE:**
- MAXIMUM DESIGN EARTHQUAKE 8 MAGNITUDE
- DESIGN EARTHQUAKE 7 MAGNITUDE (as per MSK-64)

**MAIN BUILDING**
- Length 100 m
- Width 25 m
- Height 25 m
LEAK-TIGHT CONTAINMENT
OF A GROUND NPP WITH KLT-40S RP

- Diameter: 24 m
- Height: 36 m
- Mass: 300 t
- Volume, gross: 15600 m³
RADIATION AND ENVIRONMENTAL SAFETY

SANITARY PROTECTION AREA

1 km

EMERGENCY RESPONSE AREA

POPULATION EXPOSURE DOSE RATE
- UNDER NORMAL OPERATION – 0.01%
- UNDER LARGEST-BREAK LOCA - 5% OF NATURAL BACKGROUND RADIATION

POPULATION EXPOSURE DOSE IN BEYOND-DESIGN BASIS ACCIDENT WITH SEVERE CORE DAMAGE DOES NOT EXCEED 5 mSv
FACTORY FABRICATION, MINIMAL STARTUP-ADJUSTMENT REQUIRED ON SITE, SIMPLIFIED SYSTEMS AND STRUCTURES

LOW FUEL COMPONENT, LARGE LIFETIME AND SERVICE LIFE, MINIMUM SHIFT PERSONNEL

COMMON MAINTENANCE INFRASTRUCTURE PROVIDING CORE RELOADING, SPENT FUEL HANDLING AND DISPOSAL

LONG-TERM PERIOD OF CONTINUOUS WORK, LONG FUEL LIFE

SIMPLICITY OF DECOMMISSIONING DUE TO MOBILITY OF POWER UNIT (FLOATING OR GROUND)

SAVING OF ORGANIC POWER SOURCES (PROFIT FROM THEIR SALE ON DOMESTIC AND FOREIGN MARKET)

REDUCTION OF EMISSIONS AND RELEASES INTO THE ENVIRONMENT
CONCLUSION

Main advantages of small NPPs are conditioned by their mobility, serial factory construction, long service life, available maintenance basis, minimum capital and operation costs.

Reactor plants developed by OKBM on the basis of shipbuilding technologies for power units with unit electric power of 3-40 MW and higher (to 600 MW) can be supplied commercially under conditions of existing factory cooperation.

Basic properties:
- High reliability proven by operation experience of marine propulsion RPs;
- Compliance with the modern international safety requirements;
- Compliance with the nuclear materials non-proliferation criteria.
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