Status of SMR development and deployment of SMRs in the Russian Federation

V.M. Belyaev, A.N. Pakhomov, K.B. Veshnyakov
OKBM Reactor Technologies: Experience and Development

Foundation of proven technologies and development

Great experience in development and operation of marine reactor plants

Key fields of activities:
• Standardization of engineering decisions for the entire power range;
• Increase of reliability, safety, manoeuvrability;
• Reduction of the scope of maintenance, increase of service operation between repairs.

Great experience in development and operation of nuclear icebreakers reactor plants

• Total number of reactor plants is 20 pcs. (including 7 RPs installed on the acting nuclear icebreakers).
• 60 years of 3 generations of nuclear icebreakers operation in the Arctic region.
• Total operating time is more than 400 reactor-years.
• Six innovation RITM-200 RPs have been supplied for the three multipurpose nuclear icebreaker.

Experience in development and fabrication of reactor plants for the floating nuclear power plants

• Two RPs have been supplied for the FNPP “Academician Lomonosov” confirming the efficiency of combining the functions of Chief Designer and Complete Supplier of KLT-40S RP.

• Proven reactor technologies and innovation solutions are available.
Floating NPP Based on FPU with KLT-40S RPs

**Product**
- **Electric power**: 20…70 MW
- **Heat**: 50…146 Gcal/h

**Reactor plant**: KLT-40S
**Number of RPs**: 2 units
**Electric power**: 2x35 MW
**Time interval between refueling**: 2.5-3 years
**Operating time**: 40 years

**New class of power sources**
- The power unit comprises two reactor plants, two turbine plants, electric-power system, refueling complex, nuclear fuel and radioactive waste storage, accommodations.
- An autonomous power unit is mounted on the non-self-propelled barge. The number of offshore facilities and requirements for them are minimal.
- The power unit is supplied to the operation site by water on a turnkey basis after completed acceptance tests.
- After completion of four cycles, it is transported to a specialized enterprise to be repaired.
- It is possible to change the power unit location site.
- After decommissioning on termination of the service life, the floating power unit is transported to its disposal site providing retention of the “green lawn” state in the floating NPP operation area.

**Site**
- Distant or isolated regions (Pevek town – site for first of a kind NPP)

**Competitive advantages**
- Compactness
- High maneuverability
- Prefabrication

**Pilot design of Small NPP**
- FPU trials are complete
- NPP start up is scheduled for 2019 - 2020
New Generation of Nuclear Icebreakers. Multi-purpose Nuclear Icebreaker with RITM-200 RPs

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP thermal capacity</td>
<td>2x175 MW</td>
</tr>
<tr>
<td>Propulsion capacity</td>
<td>60 MW</td>
</tr>
<tr>
<td>Displacement</td>
<td>33 530/ 25 540 t</td>
</tr>
<tr>
<td>Draft</td>
<td>10.5 /8.55 m</td>
</tr>
<tr>
<td>Icebreaking capability</td>
<td>2.8 m</td>
</tr>
</tbody>
</table>

Commissioning schedule:
- “Arctica” 2020
- “Sibir” 2021
- “Ural” 2022

Two additional multi-purpose nuclear icebreakers are planning.
RITM-400 RP for nuclear leader icebreaker

**Icebreaker’s purpose:** Year-round escort of large-capacity vessels and caravans in the Arctic

**Icebreaker’s tasks:**
1. Providing year-round traffic on the Northern Sea Route regardless of weather and ice conditions.
2. Ensuring year-round export of hydrocarbons from the Yamal deposits to the countries of the Asia-Pacific region.

**Key features of leader icebreaker:**
- Propulsion capacity - 120 MW;
- Icebreaking capability - up to 4 m;
- Displacement - 70 600 t;
- Length - 209.0 m;
- Beam - 47.5 m;
- Draft - 13.0 m;
- Speed through ice 2 m thick - 13 knots.
- Icebreaker start up is scheduled for - 2027

Two additional icebreakers are planning
Small Land-Based NPP with Two RITM-200 RPs

<table>
<thead>
<tr>
<th>Product</th>
<th>Electric power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacity</td>
<td>105 MW</td>
</tr>
</tbody>
</table>

Reactor plant: RITM-200  
Number of RPs: 2 units  
Electric power: 2х52.5 MW  
Time interval between refueling: 6 years  
Operating time: 60 years  
Total site area: 6 ha

**Competitive advantages**
- Minimum construction site;
- Long-term operation without refueling;
- High maneuverability

**Basis for RITM-200 application**
- Completed design documentation and production equipment  
- Proved fabrication technologies  
- Established enterprise cooperation

**Status: Conceptual Design**

**Small nuclear station based on ship technologies**
- RITM-200 reactor plant of multi-purpose nuclear icebreaker was applied as a basic power source;
- The highest technical and economic indices and efficiency were achieved due to ship approaches (compactness, maneuverability, resistance to external impacts, developed self-protection properties);
- Meeting all current global requirements and trends in nuclear facility safety area;
Small Floating NPP Based on Optimized FPU with Two RITM-200M RPs

Product

<table>
<thead>
<tr>
<th>Electric power</th>
<th>Product Electric power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacity</td>
<td>100 MW</td>
</tr>
<tr>
<td>Reactor plant</td>
<td>RITM-200M</td>
</tr>
<tr>
<td>Number of RPs</td>
<td>2 units</td>
</tr>
<tr>
<td>Electric power</td>
<td>2x50 MW</td>
</tr>
<tr>
<td>Time interval between refueling</td>
<td>10 years</td>
</tr>
<tr>
<td>Operating time</td>
<td>60 years</td>
</tr>
<tr>
<td>OFPU length</td>
<td>112 m</td>
</tr>
<tr>
<td>OFPU beam</td>
<td>25 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>12000 t</td>
</tr>
</tbody>
</table>

Variability

- Non-self-propelled vessel
- Rigid mooring at OSHS*
- Self-propelled vessel
- Self-positioning in open water area

Competitive advantages

- Long-term operation without refueling;
- High maneuverability
- Exclusion of operation with nuclear fuel on site
- NPP design and equipment unification

Status: Conceptual Design

Additional optional features

- Heating cogeneration equipment
- Desalination equipment

Increase FPU Commercial Appeal

- Ensuring of operation without refueling at location site till dock (factory) repair
- Exclusion of refueling complex and storage of spent fuel and solid radwaste from the FPU design
- Exclusion of accommodation from the FPU design

*OSHS – on-shore hydraulic structures
**KLT-40S, RITM-200, RITM-200M and RITM-400 RP. Comparative Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>KLT-40S</th>
<th>RITM-200</th>
<th>RITM-200M</th>
<th>RITM-400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total assigned service life, h/year</td>
<td>300 000/40</td>
<td>500 000/60</td>
<td>480 000/60</td>
<td>320 000/40</td>
</tr>
<tr>
<td>Assigned life time/service life till factory repair, h/years</td>
<td>100 000/12</td>
<td>250 000/30</td>
<td>160 000/20</td>
<td>160 000/20</td>
</tr>
<tr>
<td>Number of medium repairs</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mass of two RPs in the containment, t</td>
<td>3743 t</td>
<td>2200 t</td>
<td>2600 t</td>
<td>3890 t</td>
</tr>
<tr>
<td>Containment dimensions for two RPs LxWxH, m</td>
<td>12x17.2x12 m</td>
<td>6x13.2x15.5 m</td>
<td>6.8x14.6x16.0 m</td>
<td>8.96x18.2x17.5 m</td>
</tr>
<tr>
<td>Core refueling interval, years</td>
<td>2.5 (3.0) years</td>
<td>5.7 years</td>
<td>10 years</td>
<td>5.7 years</td>
</tr>
<tr>
<td>RCP power, kW</td>
<td>4x152 kW</td>
<td>4x97 kW</td>
<td>4x97 kW</td>
<td>4x235 kW</td>
</tr>
<tr>
<td>Passive heat removal, h</td>
<td>24 h</td>
<td>∞ h</td>
<td>∞ h</td>
<td>∞ h</td>
</tr>
<tr>
<td>Time until core uncover in a passive accident scenario with primary leakage, h</td>
<td>10 h</td>
<td>72 h</td>
<td>72 h</td>
<td>12.7 h</td>
</tr>
<tr>
<td>Plant</td>
<td>RP Weight in the Containment</td>
<td>RP Dimensions in the Containment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------</td>
<td>----------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KLT-40S</td>
<td>1870 t</td>
<td>12 x 7.9 x 12 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RITM-200</td>
<td>1100 t</td>
<td>6 x 6 x 15.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RITM-200M</td>
<td>1300 t</td>
<td>6.8 x 6.7 x 16.0 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RITM-400</td>
<td>1945 t</td>
<td>9 x 8.2 x 17.5 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RITM-200M RP. Main Engineering Solutions

1. The RP has integral design of the reactor with forced circulation of the primary coolant and remote gas pressure compensation system.
2. Composition and structure of the RP systems are designed considering experience gained while developing the previous plant generation, requirements of the up-to-date norm safety documentation, ToR requirements with regard to weight-dimensional characteristics and reduction of liquid radwaste.
3. The main design approach is rational combination of passive and active safety means and trains, optimal use of the normal operational and safety systems.
   - Passive pressure reduction and cooling down systems are introduced (efficiency of the systems is confirmed by bench testing);
   - Pressure compensation system is divided in two independent groups to minimize diameter of coolant leak;
   - Main circulation path of the primary circuit is located in a single vessel;
   - Header scheme of primary coolant circulation is introduced, which ensures advanced vitality of the plant during SG and MCP failures.
Safety Provision by Active Systems in Loss-of-Heat-Removal Accidents

- **Active Residual Heat Removal**
  - 1 safety loop through steam generator
  - 1 safety loop through heat exchanger of primary circuit coolant purification loop
  - Each train provides heat removal from the core to the heat sink with account of single point of failure.
  - BDBA management is performed by water supply from condensate-feeding system of steam-turbine plant.

**Actuation**
- Automatically by emergency protection signals
- Remotely by operator from central control panel
- From local post

- Passive Residual Heat Removal
  - 2 safety loops with coolant circulation from water tanks through steam generators. Evaporated water condenses in air-to-water heat exchangers and flow back to tanks
  - Each train provides heat removal from the core to the heat sink with account of single point of failure.
  - Safety provision using passive means for not less than 3 days
  - BDBA management is performed by water supply from condensate-feeding system of steam-turbine plant.

- Actuation
  - Automatically by blackout signals;
  - Remotely by operator from central control panel;
  - From local post;
  - From hydraulically-controlled air control valve by direct impact of emergency primary circuit pressure
Safety Provision at Primary Depressurization

**Active Systems**
- 2 active trains of core cooling down (from make-up pumps);
- Train of cooling down through SG;
- Double localizing valves (at inter-circuit leakage).

**Passive Systems**
- 2 passive trains with hydraulic accumulator of core cooling system;
- 2 trains of passive system of cooling down by secondary circuit.

**Actuation**
- Automatically by emergency protection signals at primary circuit leakage
- Remotely by operator from central control panel;
- From local post (outside containment);
Safety Provision at Overpressure in Containment

Passive Means
- 2 passive trains to decrease emergency pressure in containment;
- Localization of steam-water mixture in LOCA within containment of emergency reactor plant;
- Integration of containment into united space due to safety device actuation.

Actuation
- Automatically by emergency protection signals at primary circuit leakage
- Remotely by operator from central control panel;
- From local post
Radiation and Environmental Safety

- Population radiation dose rate under normal operation conditions and design-basis accidents does not exceed 0.01% of natural radiation background.
- Population is allowed to live in the protective action planning area. No compulsory evacuation planning area.

Diagram:
- BUFFER AREA
- PROTECTIVE ACTION PLANNING AREA
- 1 km
Conclusion

- JSC “Afrikantov OKBM” has developed and is implementing innovative Reactor plant designs enabling to create a power range of NPPs of various applications and arrangements.

- The designs provide high technical-and-economic indices, referentiality of the applied technical solutions and their safety is well substantiated and confirmed by many years operation of analogues and prototypes.

- RITM-200 type reactor plant has advantages from the viewpoint of safety, weight-size parameters and technical-and-economic indices.
THANK YOU FOR YOUR ATTENTION!