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Fast Neutron Reactor Plant Equipment Upgrading

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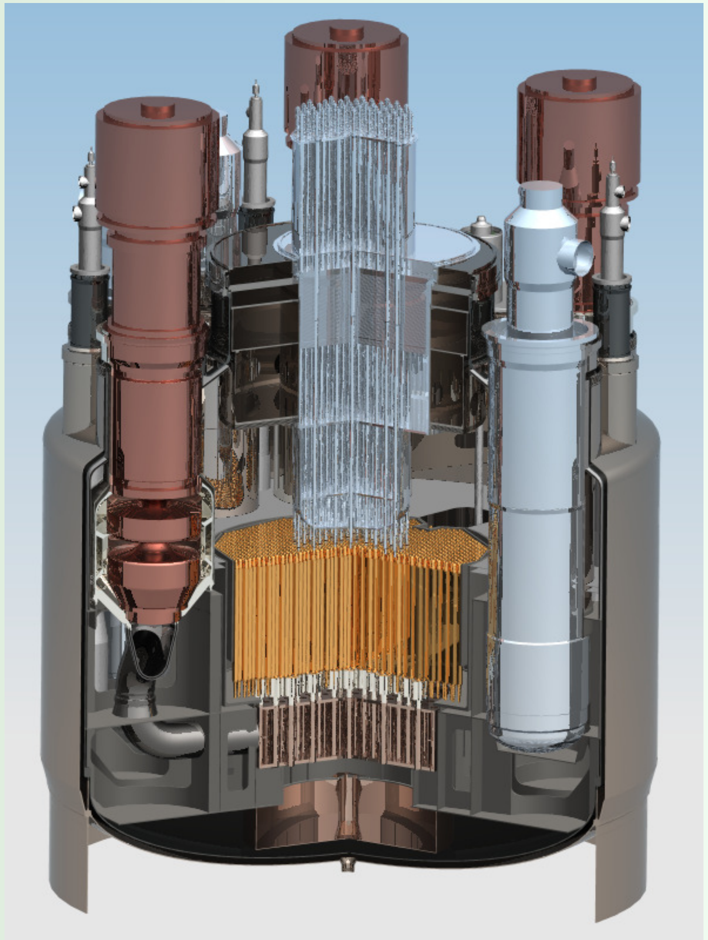
The Subject

✓Equipment upgrading to enhance safety, technical-and-economic performance of next generation BN-1200 RP is based on the analysis of positive experience in BN sodium fast neutron reactor development and operation and some new design solutions with account of necessary additional R&D work.

✓ The paper gives information on development of main equipment for the advanced BN-1200 reactor plant.

BN-1200 specifications

Nominal thermal power, MW	2900
Number of heat-removing loops	4
Primary coolant temperature at IHX inlet / outlet , ^{o}C	550 / 410
MCP-1 flow rate, m^3/hr (kg/s)	17945(4257)
IHX thermal power, MW	4x725
Number of CTs	3
Autonomous HX thermal power, MW	4x20
Air HX thermal power, MW	8x10
SG thermal power, MW	8x362.5
Electric power, MW	1200
Capacity factor	0.9
Assigned lifetime, years	60

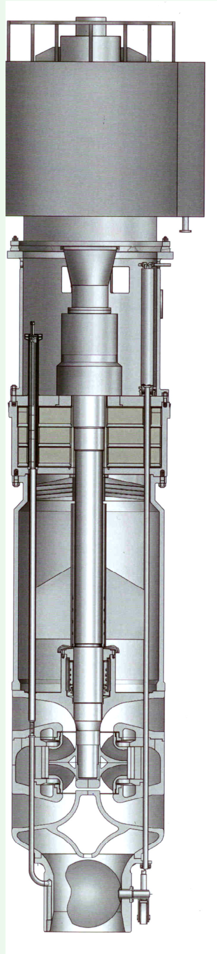


Main Circulation Pumps of the Primary Circuit

✓The BN-1200 MCP-1 is a submerged, centrifugal, vertical, single-stage pump with double-sided suction and bottom hydrostatic bearing.

✓ Long-term operation of the BN-600 MCP-1's has revealed the factors limiting their useful life. Mainly, it is cavitation-erosive wear of impeller blades.

✓ In order to develop the BN-1200 RP MCP-1 that meets the imposed requirements, design options with different rotor rotation speeds, different impeller and diffuser designs are being studied. The studies aim at the possible increase in the impeller lifetime from 4.5 (BN-800 MCP-1) to 16 years.



MCP-1

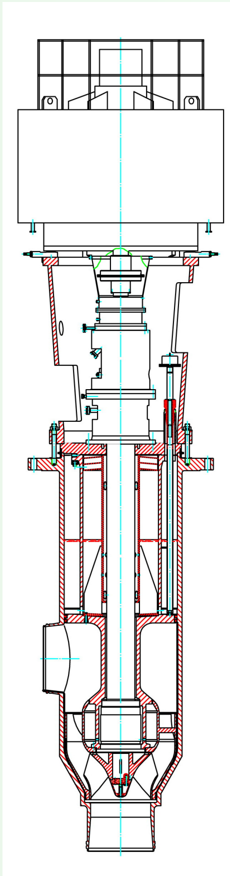
Main Circulation Pumps of the Secondary Circuit

✓The BN-1200 MCP-2 design is based on the solutions verified by long-term operation of BN-600 MCP-2.

✓The BN-600 MCP-2 lifetime characteristics equal to 14.4 and 16 years, which was confirmed by operating experience, are close to those required for BN-1200 MCP-2.

✓It is a centrifugal, vertical, single-stage pump with single-sided suction, bottom hydrostatic bearing and free sodium level.

✓Experimental studies of flow paths were planned using scaled models, MCP-1 and MCP-2 prototypes testing with motor drives at the full-scale water test facility.



MCP-2

Intermediate Heat Exchanger

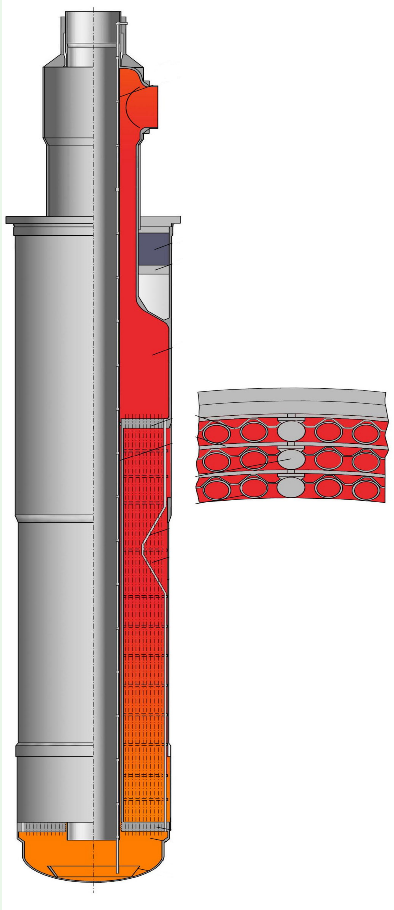
✓The design solutions accepted for BN-800 and BN-1200 IHX were validated by IHX reliable operation in BN-600 under similar conditions.

✓The design incorporates a central downcomer pipe for secondary circuit sodium and straight heat-exchange pipes with compensating bends.

✓After 25 years in operation, one of six BN-600 IHXs was removed. Its inspection revealed no changes, which could be an obstacle on the way to extend lifetime of existing IHX to 45 years.

✓Calculations that used the obtained data showed the possibility to reduce the heat-exchange tube thickness from 1.4 mm to 1 mm for the BN-1200 reactor and extend its service life to 60 years.

✓This IHX design does not require additional experimental studies.



Control Rod Drive Mechanism

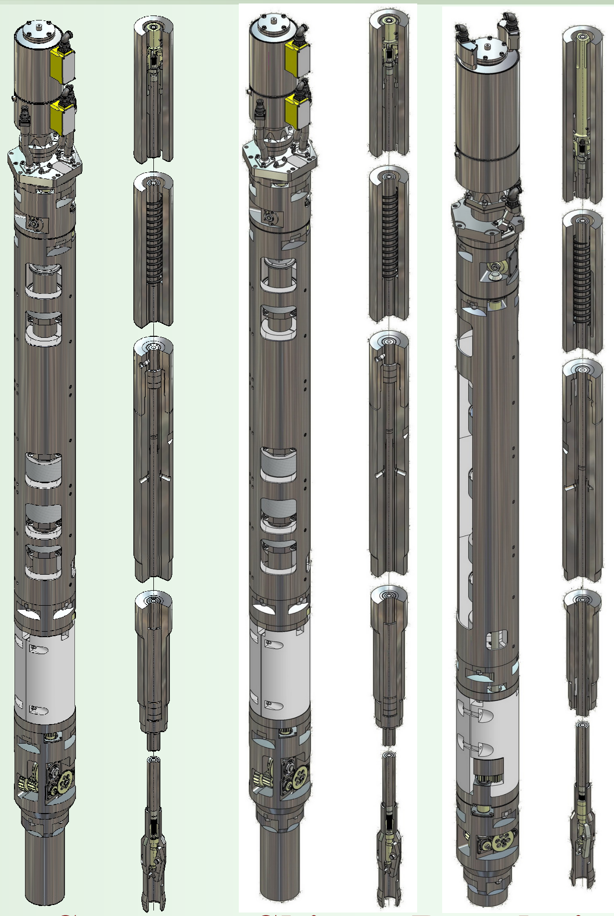
✓ The BN-800 and BN-1200 CRDM design is largly based on the solutions validated by BN-600 operating experience.

✓ Application of a step motor that simplifies the kinematic scheme and improves its reliability is a basis for BN-800 and BN-1200 CRDM design upgrading.

✓The CRDM assigned lifetime is 30 years.

✓Some of the BN-1200 control rods work in the passive emergency protection mode due to free suspension in sodium (hydraulically suspended rods).

✓ CRDM prototypes will be tested to meet regulatory documentation requirements.



Scram rod | Shim rod | Regulating rod

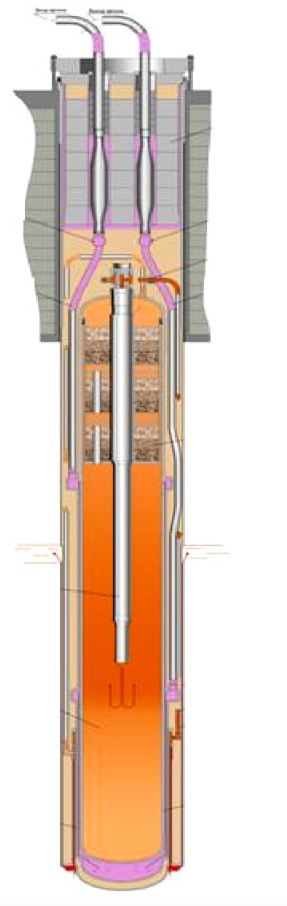
Built-in Cold Trap

✓ Unlike the BN-600 and BN-800 designs, the BN-1200 cold traps are arranged immediately inside the reactor vessel, which made it possible to remove outer pipelines and completely exclude radioactive sodium leaks.

✓Two types of cold traps are used: one with and another one without a recuperator. The CT with a recuperator is used for sodium purification during reactor power operation and refueling. The CT without a recuperator is used during reactor refueling in case of increased sodium contamination.

✓Electromagnetic pump circulates sodium through the CT, and an external gas circuit with a compressor and gas-water cooler is used to cool the CT.

✓CT mockup and prototype tests at the sodium test facility are provided for to validate CT characteristics.



Autonomous Heat Exchanger

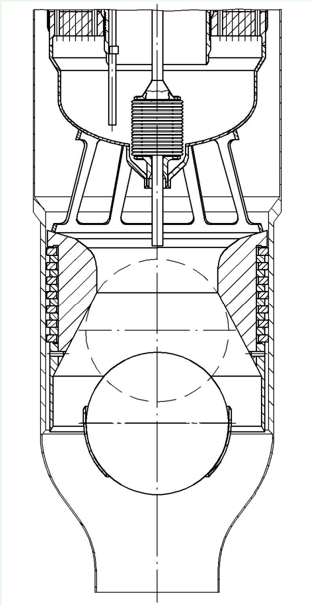
- ✓ In emergency, heat removal in the BN-600 reactor is performed by the third circuit, and in BN-800 reactor, air heat-exchanger connected to the secondary circuit performs this function.

- ✓The BN-1200 emergency heat removal system incorporates autonomous and air heat exchangers built into the reactor vessel.

- ✓The autonomous heat exchanger design solutions are analogous to those of BN-600 IHX. The main difference is the use of a passive check valve, which is located at the primary coolant outlet from the tube bundle, to ensure sodium circulation directly through fuel assembly.

- ✓In case of ball sticking in the upper position, manual opening of the check valve is ensured by a rod coming through the central autonomous heat exchanger tube.

- ✓Experiments at the water and sodium test facilities are provided for to validate the check valve design.



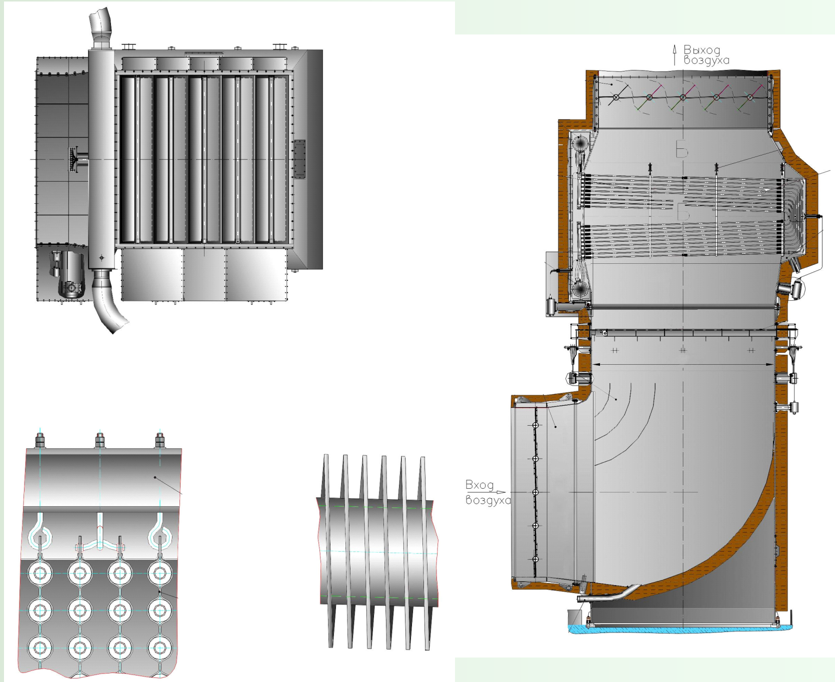
Air Heat Exchanger

✓ The BN-1200 air heat-exchanger design is entirely based on the solutions adopted in the BN-800. The only difference is in the number of sections and heat removal capacity.

✓The heat exchange surface is assembled of finned tubes.

✓The air heat exchanger lifetime was increased from 40 to 60 years.

✓The experiments are being performed as part of BN-800 studies.

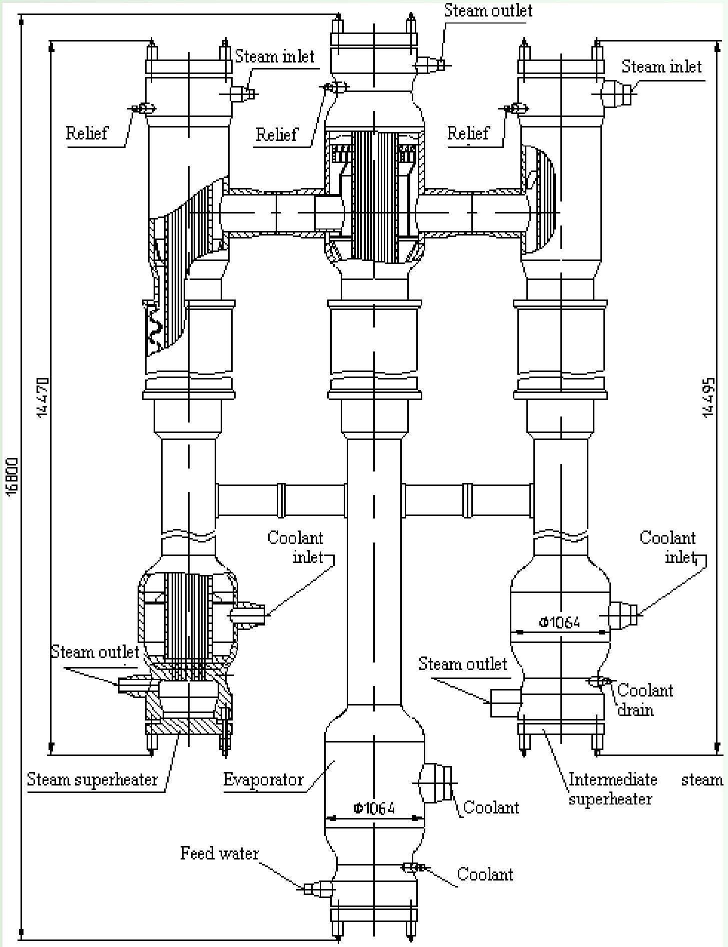


Steam Generator

✓The BN-600 RP uses section-modular type SGs. Each section includes an evaporator, steam superheater and a sodium superheater for medium pressure steam.

✓A similar design is used in the BN-800 RP but without the sodium steam superheater. Live steam ensures superheating of the medium pressure steam, which simplifies the design and decreases SG materials intensity.

✓These SGs are highly reliable and in case of an interloop leak, a single section can be isolated in them without reactor shutdown or power decrease. However, this concept has significant disadvantages due to high specific metal intensity and branching network of pipelines with valves.



BN-600 SG

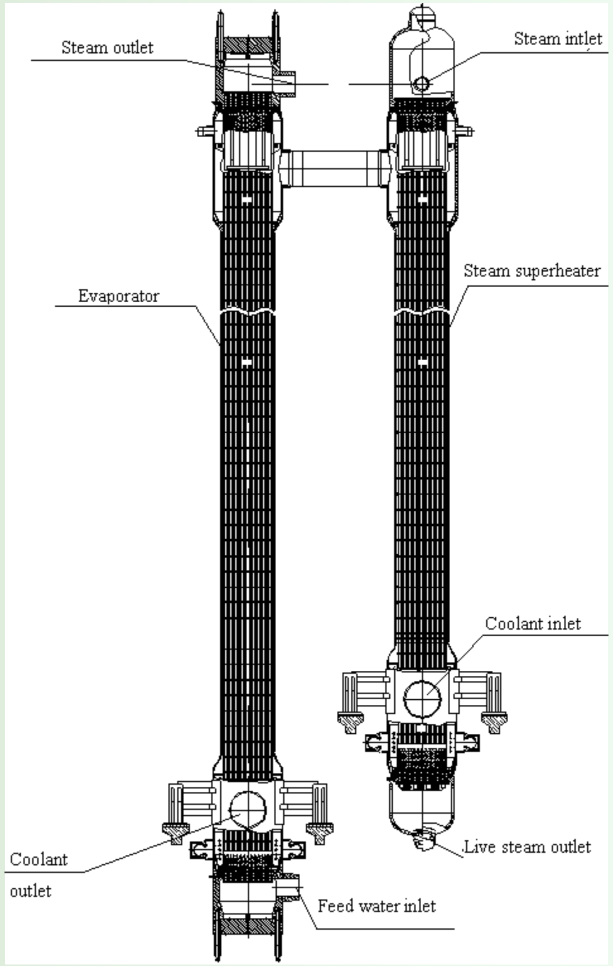
BN-1200 Steam Generator

✓The BN-1200 reactor design uses a casing-type SG with two sections in each loop.

✓Unlike the BN-600 and BN-800, the BN-1200 SG will be made of chromium steel. The use of the new structural material will reduce the heat exchange tube thickness from 3.0 mm to 2.0 mm and extend the SG lifetime from 20 to 30 years.

✓Application of the casing-type design and increased section power improved the SG and RP mass and size characteristics.

✓Experiments with models and tube bundle fragments at the sodium test facilities are provided for.



Conclusion

✓ Development of BN-1200 equipment is based on extensive Russian experience in designing and operation of sodium-cooled fast reactors.

✓Well-tried and new technical solutions combined make it possible to quickly develop reliable equipment having high technical-and-economic performance and safety level.

Thank you