BN-600 POWER UNIT 15-YEAR OPERATING EXPERIENCE

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Abstract

Comprehensive experience has been gained with the operating fast reactor BN-600 with a power out put of 600 MWe. This paper includes important performance results and gives also an overview of the experience gained from BN-600 NPP commercial operation during 15 years.

1. CORE AND BLANKET

The uranium fueled core was designed to consist of two 21% and 33% uranium-235 enriched zones, to obtain a 9.7% ha peak burnup. However, operating experience which has been accumulated by the time of the BN-600 commissioning led to the limited burnup of 7.3% ha and to 100 efd interval between the refuellings to be carried out three times a year. In spite of decreased burnup levels considerable number of fuel failures was still observed by the end of each operating cycle. In order to improve fuel performance the core was modified in 1987, as follows: a) three uranium enriched zones (17-21-26% enrichment, 8.3% peak burnup) were introduced; b) fuel subassemblies rotation and reshuffling were terminated, and c) core part height was increased from 75 cm to 100 cm, thereby reducing the linear rating from 51 kW/m to 47 kW/m. The reloads were two times a year after 165 efd refuelling interval. With this new core no fuel failures actually occurred and potential for higher burnup could be further realized. In 1993, the second modification of the core took place to allow the nominal burnup to be reached. The advanced structural materials[1] have been used. With these new materials a 10% ha peak burnup was obtained. This core was qualified as standard. Nowadays the possibilities are in hand to provide for the third modification of the core with more than 11% ha burnup. This would allow to increase intervals between refuelling which is important in view of the local conditions necessitating co-generation of heat for central heating in wintertime. Work on increasing burnup levels involved in-reactor testing of series of experimental subassemblies there were 5552 experimental subassemblies (more than 70,000 fuel pins). The uranium-plutonium vibracompacted fuel testing was finished successfully and standard MOX fuel testing is continued. A much longer lifetime of control rod guide tubes (from 200 to 640 efd), due to advanced structural materials, is another important result of a 15-year operation period.

2. REACTOR AND PRIMARY CIRCUIT SYSTEM

The BN-600 reactor is of the pool type, (Fig. 1.) i.e. besides the core and in-reactor components the reactor vessel encloses the entire primary heat transfer system comprising primary sodium pumps, sodium-sodium intermediate heat exchangers and pipe manifold. *The primary sodium pumps* are characterized by successful operation. At the beginning some failures of gear couplings took place. The failures were caused by coincidence of shaft

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[1] See paper F.M. Mitenkov "LMFRs design and operation experience"

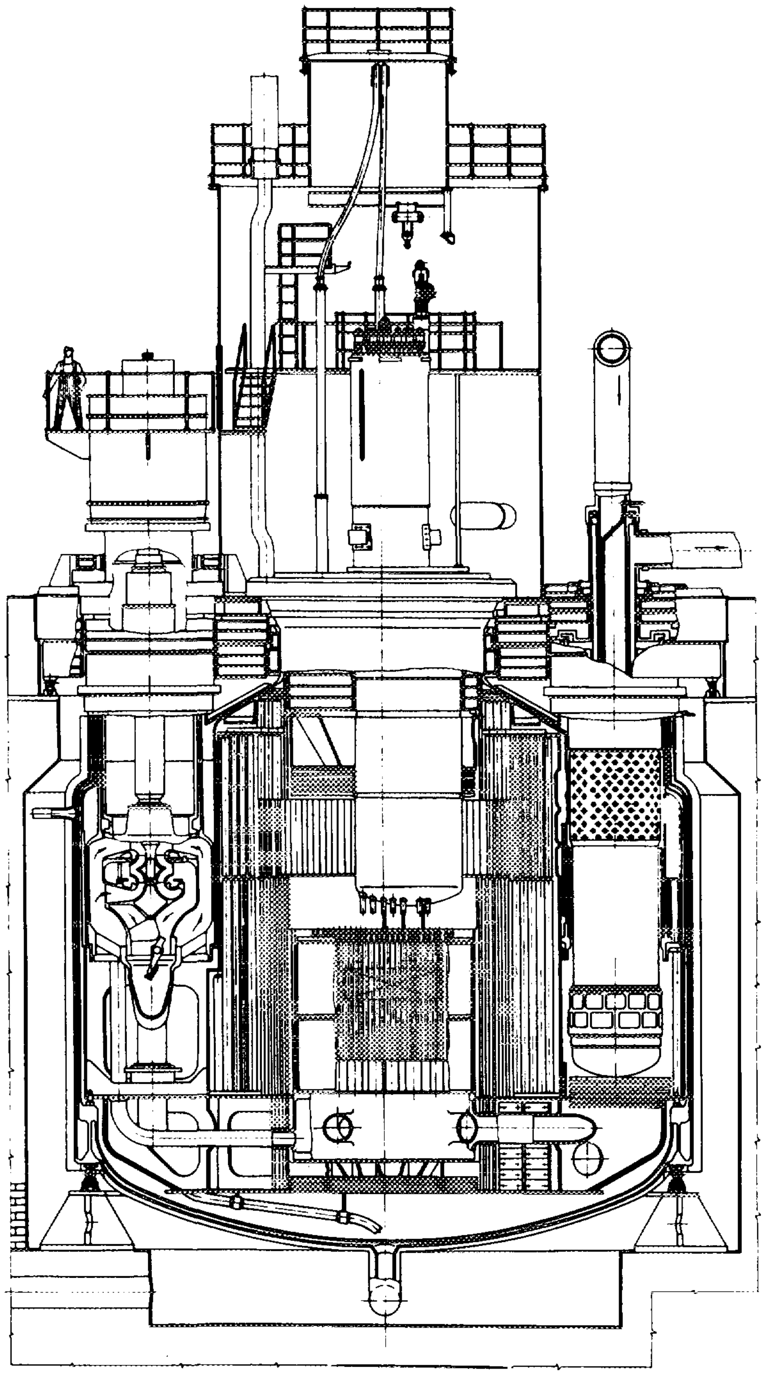

Fig. 1. BN-600 reactor

resonance frequencies and frequencies of torsional vibrations. After the cause had been identified and rotational frequency had been adjusted away from the resonance no failures occurred. The work on improving pump performance resulted in longer lifetime of the main pump components, the most important achievement being extension of impeller lifetime up to 50,000 running hours. Valuable experience was accumulated on replacement of removable pump components. There were two interventions on each primary pump to replace impellers after expiring their lifetime. The *intermediate heat exchangers* have been in trouble-free operation.

3. STEAM GENERATORS AND SECONDARY CIRCUIT SYSTEM

The secondary heat transfer system consists of three loops, and each of them consists of a steam generator, a secondary sodium pump and pipe manifold. *A steam generator* (Fig. 2) is a set of modules of three types, with evaporating, superheating and reheating modules (8 modules of each SG). Three modules: evaporator, superheater and reheater represent the SG section (in total a steam generator has 8 sections) which can be isolated using gate valves both on sodium and water-steam side. In the case of a water-into-sodium leak in one of the modules of any section, the latter to be isolated using gate valves thereby permitting to proceed the steam generator operation practically without reduction in NPP overall capacity. The operating experience had validated the flexibility of module type steam generator concept. Whereas 12 water-into-sodium leaks occurred, the electrical generation loss attributable to this cause was only 0.3%. Valuable work was done on evaporator lifetime extension from 50,000 to 105,000 running hours necessitating only one replacement of each evaporator module within the reactor lifetime instead of three replacements. The longer evaporator lifetime was based on the results from the extensive research programme and was contributed by improving water chemistry, decreased rate of the transient and emergency conditions against the design value, periodical re-agent cleaning, and water washing for friable deposit removal. Nowadays the planned replacement of the evaporators are under way. *The secondary sodium pumps* have been essentially in trouble-free operation. On the basis of the research programme their lifetime was extended up to 105,000 running hours.

4. TURBINES AND WATER-STEAM CIRCUIT SYSTEM

The turbines installed in the BN-600 power unit are of conventional design. They are characterized by successful operation. *The drain lines and valves* have been major contributors to the incident rate for latest years. Now just their performance is considered to be critical for the entire power unit performance.

5. ELECTRICAL EQUIPMENT

The power unit alternators are of conventional design. During the latest years the stator cooling system distillate leaks have been observed actually each operating cycle. Several times these led to unplanned heat transfer loop trips. The cause is an improper design of the valves seals.

6. INCIDENTS

None of the occurred incidents had impact on public and environment. All the incidents were beyond the OFF SITE IMPACT parameter on International Nuclear Event Scale, i.e. negligible for safety. The most serious incident (assessed as level 1 by the other parameters: *on site impact* and *in-depth protection*) was a sodium leak on the auxiliary primary sodium purification system pipeline 48 mm diameter occurred on 07.10.93 causing insignificant radioactive discharges to atmosphere which was equivalent to 0.001 buildup of natural radiation background on the boundary closest to the plant.

7. BN-600 PERFORMANCE ESTIMATION

The comparative estimation of NPP performance is a many-dimensional statistical problem, i.e. a cluster of indicators of various power units should be estimated against time distribution since the point estimation for one year or an individual plant is not representative

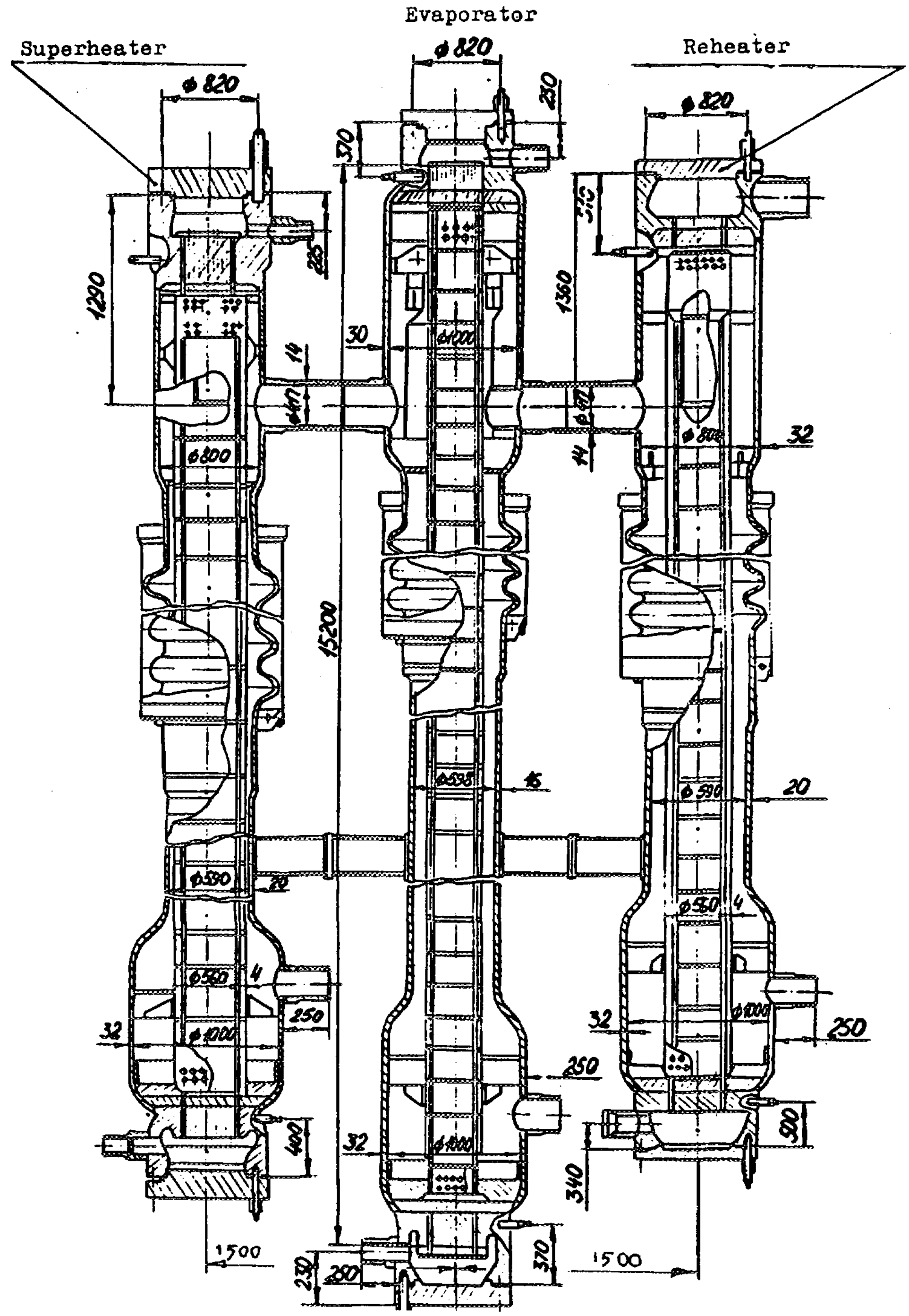

Fig. 2. BN-600 steam generator

due to discrepancy of annual individual indicator distribution estimates of the same plant and due to different operation schedules of various plants. It is also evident that the main indicator of good plant performance should be a total steady operation criterion rather than individual annual parameter achievements. Since statistical distribution of any indicator bears no symmetry, a sample median should be the main statistical estimate of an indicator. As regards an individual plant the median is a indicator value maintained throughout half period of the plant history. By analogy as regards a cluster of plants the median is an indicator value attributable to half of the plants. The comparison between the BN-600 NPP and world main NPPs performance indicators (Table 1.) has shown BN-600 to be in the top half of the world nuclear power units.

TABLE I. MAIN WORLDWIDE NPP PERFORMANCE INDICATORS

Indicator	World NPPs	BN-600
1. Load factor, %	73.0	73.2
2. Unplanned production losses, %	3.9	2.7
3. Reactor scrams per 7000 hours	1.1	0.0
4. Collective personnel dose, manSv	2.0	1.0
5. Low active solid waste, m^3	100.0	62.0

10. CONCLUSION

1. The 15-year operation period have demonstrated reliability and safety of the pool sodium-cooled fast reactor power unit BN-600 with the module steam generators.

2. The main performance indicators place the BN600 in the top half of the world power units that should be characterized as achievement of the commercial NPP performance level. These indicators are better than similar indicators of other fast reactors in the world.

3. The BN-600 operating experience is essential for designing next generations of fast reactors, in the Russian Federation.