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STAFFING REQUIREMENTS FOR FUTURE SMALL AND MEDIUM REACTORS BASED ON PROJECTIONS IN THE RUSSIAN FEDERATION

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Abstract

Experimental Design Bureau of Mechanical Engineering (OKBM) specializes in the development of small and medium power reactors having different purposes. They include reactor plants for NPHPP, nuclear district heating power plants and propulsion plants. Small and medium power plants have simpler processes of electricity and heat production, less systems, simpler control algorithms and considerably enhanced inherent safety properties. These plants are mainly equipped with passive safety systems. These properties are especially characteristic for reactor plants of nuclear district heating power plants and HTG reactor plants. The designs of small and medium power plants actually provide a high degree of control automation which considerably reduces workload on the personnel in both normal and abnormal operation conditions. All this allows the reduction in personnel for small and medium power reactors if compared to high capacity reactor plants. But due to objective reasons the specific number of personnel (man/MW) for average and especially small capacity reactors considerably exceeds the value for high capacity reactor plants. At the same time one can propose a set of organization — technical measures allowing the increase in this value in future. Safety requirements imposed for small and average capacity reactors are the same or more strict than those for high capacity reactors. That's why the requirements to the training of personnel for such reactor plants are not allowed to be lowered if compared to the requirements imposed to the personnel of high capacity reactors.

1. INTRODUCTION

Small and medium power nuclear plants of various purposes are being now developed in Russia and abroad. They include NPHPP, nuclear district heating power plants.

The main potential customers of these plants are developing countries, regions with non-developed energy infrastructure, for example, due to hard climate, etc.

Technical and economic peculiarities of power plants with average and, especially, small capacity reactors are reflected on various aspects of their operation including the requirements to the personnel.

The present report contains certain results of the analysis dedicated to the influence of nuclear power plants with small and medium power reactors on the personnel with account of previewed design solutions and accumulated operation experience.

Average and small capacity NPPs being developed by OKBM.

OKBM belongs to Russian leading design bureaus developing nuclear power plants.

The development of nuclear propulsion power plants is one of the OKBM's main specialization's. These plants include practically all submarine and navy ship power plants and all nuclear power plants for the civil fleet.

OKBM also developed a set of reactor plant designs for small and average capacity energy and heat co-production power plants and district heating power plants.

The most famous designs of small and average capacity reactors include:

— reactor plants of ABV type;
— reactor plants of KLT type;
— reactor plants of ATETs type;
— reactor plant VPBER-600;
— reactor plant AST-500;
— reactor plant with gaseous coolant (VGM, GT-MHR).

The main performances of these power units with the specified reactor plants are given in Table 1.

Table 1. Main performances of nuclear power plant power units developed by OKBM

Parameter	VPBER-600	ATETs	KLT	ABV	AST-500	VGM	GT-MHR
Thermal power, MWt	1800	690	150	54	500	200	600
Electric power, MWe	640	230	35	12		77	285
Quantity of heat produced, GKal	1050	170	25	24	430		

It should be noted that reactor plants except the reactor plant AST-500 developed specially for district heating power plants represent multipurpose power sources which can be used for electricity, heat, desalinated water production, etc.

The market of small and average capacity reactors exists and is supposed to exist for a long time. That's why the associated problems remain actual and there is time to solve them.

What's the principal difference between small and medium power reactor plants and high capacity ones.

Small and medium power plants have simpler processes of electricity and heat production and relatively smaller number of systems. Together with a simple reduction in number of auxiliary equipment and systems because of lower power, small and medium power reactor plants have simpler steam production procedure, as a rule, with the use of one through steam generators. Often these plants are equipped with integral or unit reactors, and this fact considerably simplifies the primary circuit by due to the absence of main circulation pipelines. The heat production procedure is considerably simplified for AST-type plants. Only water circuits are used. The usage of direct gas-turbine cycle is adopted for gas cooled reactor plants and the thermal energy is converted into electricity in the primary circuit.

Small and medium power plants are characterized by considerably enhanced inherent safety properties: the level of natural circulation is higher, reactors with natural primary circulation are very frequently used for the plants, the specific volumes of primary coolant are higher, the primary circuit has enhanced accumulative capacity, etc.

These plants are mainly equipped with passive safety systems. These solutions are especially characteristic for district heating power plants and HTGR.

Small and average capacity plants have simpler control algorithms.

All the abovementioned leads to the fact that the solution of control automation problems associated with average and, especially, small capacity reactor plants is simpler provided the control system cost is minimal.

Higher level of small and average capacity reactor plants control automation considerably reduces the workload on the operation personnel in both normal and abnormal operation conditions and has a favorable effect on the reduction in power plant operation personnel.

Number of personnel for small and average capacity nuclear power plants

The analysis of personnel number at power plants of various capacity shows two main problems:

– reduction in total NPP personnel number in case of power reduction;
– increase in specific personnel number (man/MW) for medium and, especially, small power reactors.

Specified dependencies of industrial-production personnel number and industrial-production personnel specific number from power are given in Table 2.

Table 2. Operation personnel number and operation personnel specific number of domestic power plants

	NP-1100	AES-91	AES-92	NP-500	VPBER-600	GT-MHR	ABV-6
Power, MW(e)	1150	1074	1068	645	640	285	12
Personnel, men	325	349	320	303	273	230	103
Specific number, man/MW(e)	0.283	0.325	0.3	0.47	0.428	0.8	8.5

The reduction in overall NPP personnel in case of power reduction can be explained by a set of reasons, i.e.:

- reduction in the quantity of equipment associated with power reduction and reduction in the quantity of service and auxiliary systems;
- simplification of technological systems and equipment in case of reduction in its unit power;
- automation of monitoring and control, introduction of diagnostic systems.

The reduction in the main component of the total NPP personnel number - industrial-production one - is considerably smaller than that in NPP power. It is shown in Tables 3 and 4 containing the data on the number and structure of small and average capacity NPP personnel.

Table 3. Number of personnel for a small capacity ABV — type NPP with electric power 12 MW(e)

Title	Value
Administrative	2
Repair	36
Operation	103
Total	141

Table 4. Number of personnel for the existing Westinghouse NPP and for the design of AP-600 NPP with electric power 600 MW(e)

Department	An existing Westinghouse 2-loop	AP-600
Administration	34	35
Operations / engineering	**70**	**77**
Maintenance	**82**	**56**
Planning	4	13
HP / chemistry	**38**	**35**
Training	25	35
Contractors (including security)	85	85
Total	338	336
Operation personnel amounts to 190 and 168 respectively. Specific number is 0.317 and 0.28 man/MW		

The analysis of the specified data shows that the number of the operation personnel for a NPP equipped with small and average capacity reactors deviates not more than by 3 times, the power being reduced from the maximum to the minimum — from 600 MW(e) to 12 MW(e).

That's why the specific number of the personnel (man/MW) considerably increases if the power of a NPP is reduced.

This factor is considerably higher for average and, especially, small capacity reactors than for high capacity ones (see Table 2).

The number of NPP personnel is defined basing upon the regulations in force and design documentation requirements for the equipment being used at a specified power unit. So, there are two possibilities to control this factor.

From one hand, this is the upgrading of regulations. It should be noted that regulations concerning the number of personnel are possible to be revised only basing upon operation experience. In this case the policy of utilities aiming at the reduction of operated NPPs costs should be the governing factor.

At present, the number of Russian NPPs personnel is being optimized. The fact that repair personnel is no longer included in the NPP personnel made the number of personnel for new designs of domestic NPPs closer to that of foreign NPPs equal in power.

From the other hand, the equipment being designed by design institutions for future NPPs requires minimal operation maintenance without reduction in its reliability; the control system automation level is increased, diagnostic systems are introduced, etc.

Reactor plants of Russian nuclear-powered ships can be cited as an example of positive results achieved. At the same time it should be noted that high compactness and minimal maintenance of reactor plant equipment in some cases lead to a hindered access to

the equipment or to the impossibility to maintain individual elements of reactor plants in course of operation. That's why these elements are imposed to higher reliability requirements. The positive operation experience of ship reactors shows that the decision is right.

The experience of Navy reactor plants development and operation also shows that the number of personnel for small capacity reactor plants can be considerably reduced.

The number and structure of personnel for Navy reactor plants were defined basing upon the reactor plant reliability and safety analysis in a wide mode range.

The lowest operation personnel number was achieved for the reactor plant OK-550. The number of personnel for this reactor plant was 7 persons.

Even as adjusted for the longer continuous operation characteristic for NPPs and for the necessity to replace personnel in case of illness, vacation, retraining, etc., the number of personnel will not exceed 12 persons.

Specific personnel number for this reactor plant with turbine power 29.4 MW was 0.238 man/MW. This value exceeded that for up to date high capacity NPPs.

The total number of personnel with account of high degree of automation amounted to 31 person.

The implementation of modular principle in course of NPP creation is one of ways to reduce the number of personnel for NPPs equipped with small and medium power reactors. This principle previews the usage of several reactor modules with common auxiliary and service systems. The realization of such principle allows the reduction in the specific number of NPP personnel up to the level comparable to factors of NPPs equipped with high capacity reactors. Table 5 shows as an example the design number of personnel for the GA design of GT-MHR NPP with one and four reactor modules.

Table 5. Number of personnel for the GA design of GT-MHR NPP with one and four reactor modules

Department	GT-MGR one reactor module	GT-MGR four reactor modules
Number of reactors	1	4
Electric power, MW(e)	262	1050
Number of personnel, men	166	241
Specific number of personnel, man/MW	0.63	0.23

Training of personnel for small and average capacity NPPs

Safety requirements imposed to small and average capacity reactors are the same or more strict than those imposed to high capacity reactors.

As a rule, it is explained by the location of small and average capacity NPPs in the vicinity of settlements. This fact does not permit to weaken the requirements to the training of personnel for such plant if compared to high capacity reactors.

The requirements to the training of personnel for NPPs remain the same no matter the power is:

— special education is necessary;
— knowledge and understanding of processes taking place in the reactor and the main equipment of NPP;
— training at the simulators.

2. CONCLUSION

At present, the number of personnel is one of the factors influencing the performances of average and, especially, small capacity NPPs.

The specific number of personnel (man/MW) for small and average capacity reactors is considerably higher than that for high capacity reactor plants.

The OKBM's experience in development of small and average capacity reactor plants shows that this problem can be solved by means of operation and combined efforts of designers.

Main ways to solve this problem:

— creation of reactor plant equipment for small capacity NPPs requiring less maintenance if compared to high capacity NPP equipment;
— enforcement of NPP systems and equipment control automation;
— involvement of other institutions for periodic maintenance and repair;
— account of modular principle in course of NPP designing;
— modernization of regulations specifying the number and structure of small and average capacity NPPs personnel with account of accumulated design and operation experience as well as of peculiarities proper to this kind of reactors.

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