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# GENERAL PROPERTIES SAFETY OF NUCLEAR REACTORS

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**Abstract:** In this article we described the general safety properties of nuclear reactors

**Keywords:** The paper must have at least one keyword. This paragraph should be justified with a line space of exactly 11-point, special indentation of 2-centimeters and with a spacing before of exactly 48-points. The text should be set in 9-point font size and without the use of bold or italic font style. For more than one keyword, please use a comma as a separator. Keywords must be title cased.

## 1 INTRODUCTION

A high-power nuclear power plant with a PWR-type reactor. The abbreviation stands for water-cooled energy reactor - that is, in it, water acts as a coolant in the primary and secondary circuits, slowing down the nuclear reaction. And the numbers mean the electrical power of the reactor - 1.2 GW (1200 MW). Today, only in Russia there are the most modern generation “3+” nuclear power plants with PWR-1200 power units.

## 2 Security

PWR (pressurized water reactor) is one of the types of reactors that has become most widespread in modern nuclear energy. The safety systems of VVER technology have been modernized throughout all decades of its operation. When designing the latest generation of PWR reactors, the lessons of all major accidents associated with nuclear power were taken into account: at the Three Mile Island station (PWR type reactor, USA, 1979) and at the Chernobyl nuclear power plant (RBMK type reactor, USSR, 1986 G.). The result of this work was the “3+” generation reactor – PWR-1200. The first such power unit was connected to the network in August 2016 at Novovoronezh NPP-2. During its construction, unique technologies were used that were approved in the project long before the accident at the Fukushima-1 NPP (Japan, BWR type reactor, Japan, 2011 g.), but at the same time this power unit “fully complies with the post-Fukushima requirements of the IAEA.”

A distinctive feature of the AES-2006 project with the PWR-1200 reactor is the use of combined channels with passive and active equipment, which independently perform their support functions. Passive systems are capable of performing their functions without the action of active safety systems and control actions, as well as in the event of a complete shutdown of the power supply to the NPP’s own needs. Let’s consider the main innovations in the passive safety systems of the “NPP-2006” project:

- Passive heat removal system (PHRS). The system is used for long-term removal of residual heat from the reactor in beyond design basis accidents (in particular, in accidents with the shutdown of all AC power supplies).
- Containment. In the AES-2006 project, it is a double hermetic containment shell, consisting of an internal hermetic and outer containment shell. The inner shell localizes radioactive substances that are formed during depressurization of the primary circuit. The outer shell is responsible for protecting against external and reducing dynamic impacts (storms, aircraft crashes, etc.) on the equipment of the reactor compartment.
- Passive flooding of the core (hydraulic capacity of the first (HC-1) and second (HC-2) stages). In the event of depressurization of the primary circuit, HC-1, together with HC-2 and PHRS, will be responsible for cooling the core.
- Passive filtration system for the intershell space. It helps to prevent the release of radioactive substances into the environment through the outer protective shell, even if the active ventilation systems of the intershell space fail.
- Device for localizing and retaining the core melt (“melt trap”). Provides protection of the foundation from the melt, its cooling and subcriticality. In addition to innovative safety systems, the PWR-1200 reactor also has systems from previous generations of PWR reactors: a sprinkler system, an emergency gas removal system, an emergency cool-down system for steam generators, an emergency boron injection system and others. In the core, the number of absorber rod clusters has been increased from 61 to 121.Thanks to these systems, PWR-1200 fully satisfies international and Russian safety requirements.

Impact of tornadoes on structures. When a tornado passes through, the structure is affected, firstly, by wind pressure. If the size of the structure in plan is comparable to the diameter of the vortex, then when determining this load it is necessary to take into account that the wind speed in different parts of the windward surface is not the same (this is the difference between a tornado and an ordinary “flat” wind). Small elements of a structure (for example, wall panels) are calculated for maximum wind speed, and to check the stability of the entire structure (building frame), the wind load is averaged over its length. Due to inertial forces, air particles are thrown away from the axis of the vortex, as a result of which the air pressure in its middle is less than atmospheric. Therefore, the second load created by a tornado is a drop in atmospheric pressure. Because of this, the outer surfaces of the structure are under the influence of excess pressure. Finally, during a tornado, various objects are thrown into the air, and their impact on building structures must be taken into account. Usually three types of flying bodies are considered:

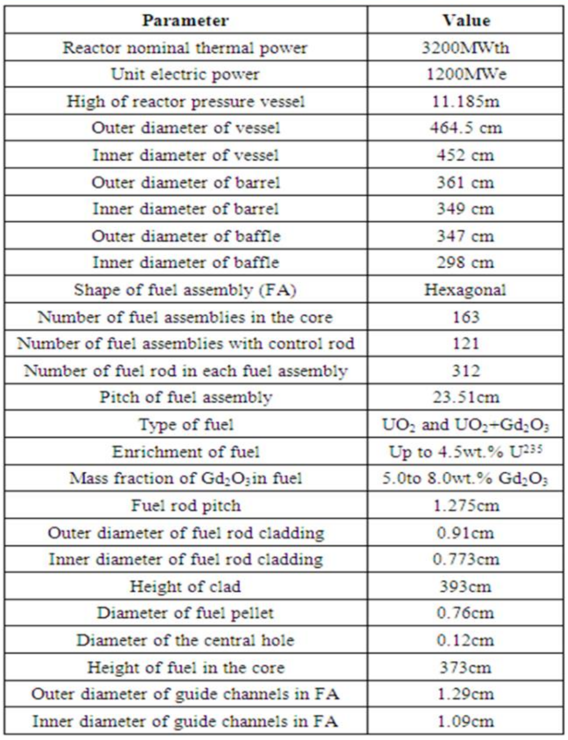
a) massive bodies with high kinetic energy, which, when colliding with a structure, cause its general deformation;

b) heavy rigid bodies leading to local penetration of protective structures;

c) small rigid bodies that can fly through ventilation and other openings into the building.

**The VVER-1200 Reactor Core Description**

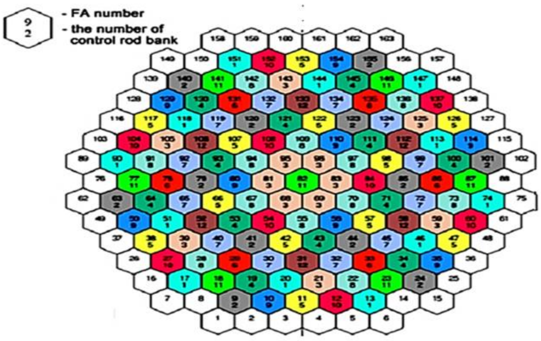
The VVER-1200/AES-2006 reactor is a pressurized water moderated reactor with thermal capacity of 3200MWth and a net electrical capacity of 1200MWe. The reactor meets all the international safety requirements for Gen III+ nuclear power plants. The main design parameters of VVER1200 core are presented in Table 1.



| Parameter | Value |
|---|---|
| Reactor nominal thermal power | 3200MWth |
| Unit electric power | 1200MWe |
| High of reactor pressure vessel | 11.185m |
| Outer diameter of vessel | 464.5 cm |
| Inner diameter of vessel | 452 cm |
| Outer diameter of barrel | 361 cm |
| Inner diameter of barrel | 349 cm |
| Outer diameter of baffle | 347 cm |
| Inner diameter of baffle | 298 cm |
| Shape of fuel assembly (FA) | Hexagonal |
| Number of fuel assemblies in the core | 163 |
| Number of fuel assemblies with control rod | 121 |
| Number of fuel rod in each fuel assembly | 312 |
| Pitch of fuel assembly | 23.51cm |
| Type of fuel | $UO_2$ and $UO_2$+$Gd_2O_3$ |
| Enrichment of fuel | Up to 4.5wt.% $U^{235}$ |
| Mass fraction of $Gd_2O_3$in fuel | 5.0to 8.0wt.% $Gd_2O_3$ |
| Fuel rod pitch | 1.275cm |
| Outer diameter of fuel rod cladding | 0.91cm |
| Inner diameter of fuel rod cladding | 0.773cm |
| Height of clad | 393cm |
| Diameter of fuel pellet | 0.76cm |
| Diameter of the central hole | 0.12cm |
| Height of fuel in the core | 373cm |
| Outer diameter of guide channels in FA | 1.29cm |
| Inner diameter of guide channels in FA | 1.09cm |

Table 1: Main design Parameters forVVER-1200/AES-2006 core

The VVER-1200 reactor core is filled with 163 fuel assemblies (FAs). Each fuel assembly consists of a head; a bundle of 331 fuel rods and a bottom nozzle. The bundle of 331 rods contains 312 fuel rods, one instrumentation channel, and 18 guide channels in which the control rods are inserted. There are six types of fuel assemblies; each one has different enrichment, different numbers of fuel pins with different enrichment (radial profiling) as well as different pin numbers with burnable absorber and weight percentage of the burnable absorber Gd2O3. The enrichment of gadolinium oxide is 5.0% and 8%. Fig. 1 illustrates the fuel assemblies' arrangement in VVER-1200 core. To control and maintain the safety of the reactor, the control and protection system (CPS) is employed. Control rods (CRs) are arranged into some groups called rod cluster control group in each fuel assembly (RCCA); each one has twenty-four control rods. RCCAs are moved by the rod cluster control (RCC) system. There are 121 RCCAs divided into twelve banks that are used for changing reactivity and for reactor shutdown in normal and emergency operation conditions. Figure 2 illustrates the control rod banks distributions in the core.



## 3 CONCLUSIONS

After reviewing this article, we came to the following conclusions:

1) Reactors of the PWR type were modernized during all operations.

2) When designing the latest generation PWR reactors, the lessons of all major accidents associated with nuclear power were taken into account.

3) Safety must be according to IAEA agency standards.

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