PIK REACTOR CONSTRUCTION STATUS

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Abstract

The 100MW reactor PIK for fundamental researches has a thermal neutron flux of more than 10^{15}n/cm^2 sec .

This presentation outlines the construction state as of 2001, its prospects and completion tactics in the conditions of unstable finance.

Construction of the reactor started in 1976. In 1986 construction of the building was completed and significant part of the installation work fulfilled. Construction of cooling systems was finished, the control panel assembled, and adjustment of the pump and gate valve control circuits started. After Chernobyl catastrophe, the USSR nuclear reactor safety requirements were revised. The PIK design did not meet these requirements and underwent considerable revision. The reconstruction design resulted in double the initial cost.

Creation of the containment was the bulkiest part of the reconstruction. It brought about the need to disassemble the roofing of the building, dismantle all the equipment of the two upper floors, and lay up the equipment of the lower floors.

As of 2001, construction in accordance with the revised design is at the stage of assemblage of the most important units, i.e. reactor itself, cooling system, heavy water system, and a number of auxiliary systems, such as depleted fuel storage, emergency cooling system etc.

1.PIK reactor

The PIK reactor is being built in the town of Gatchina, on the site of the Konstantinov Petersburg Nuclear Physics Institute of the Russian Academy of Sciences.

The PIK reactor is designed for fundamental research in the field of solid-state physics and nuclear physics [1]. The main research will be conducted on neutron beams. The trend of research on horizontal beams, on the whole, is similar to that being conducted now in the ILL and on the reactor NIST. Besides horizontal channels, the reactor is equipped with inclined and vertical channels for irradiation, material science research and certain physical research.

The main experiments will be conducted on horizontal experimental channels (HEC) designed for researching condensed-state physics and nuclear physics. It is possible that one of the through channels will be allocated for neutron silicon doping.

Inclined experimental channels are designated for material science research, for material irradiation and for neutron activation analysis.

The vertical experimental channels in the heavy-water reflector are used to place a liquid-hydrogen cold neutron source, for a graphite hot neutron source and for the irradiation of various materials.

The central loop experimental channel is designed for irradiation in very high neutron fluxes. A separate cooling circuit allows to irradiate fissionable materials.

The reactor capacity of 100 MW installed is sufficient for derivation of thermal neutron fluxes over $1\cdot10^{15}$ n/cm^{2}s in the reflector and $4.5\cdot10^{15}$ n/cm^{2}s in the central experimental channel (CEC). The installation of the CEC experimental channel in the centre of the core will undoubtedly reduce fluxes in the reflector, and an approximate 10% reduction has been estimated [2]. We have concluded such a reduction due to the fact that the record thermal neutron fluxes at the level close to $5\cdot10^{15}$ n/cm^{2}s allow us to conduct experiments, which are not feasible at the overwhelming majority of research reactors.

The main reactor layout selected long ago in 1960s has been recently recognised as the most successful, namely: a core area cooled by a light water and a reflected by heavy water (Fig. 1).

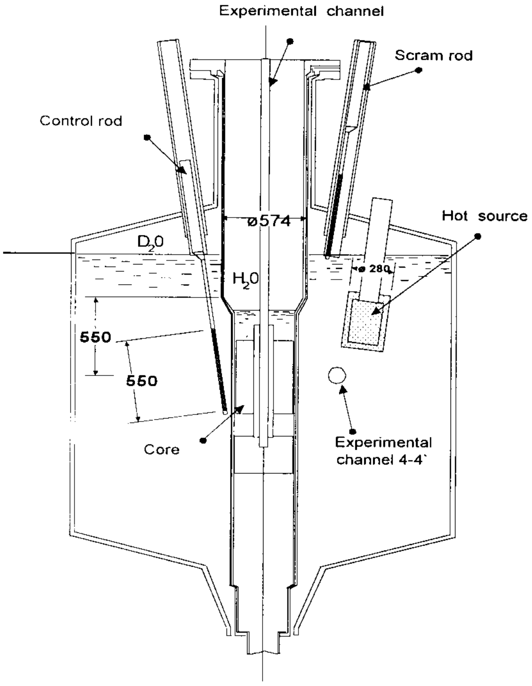

Fig. 1. Reactor PIK

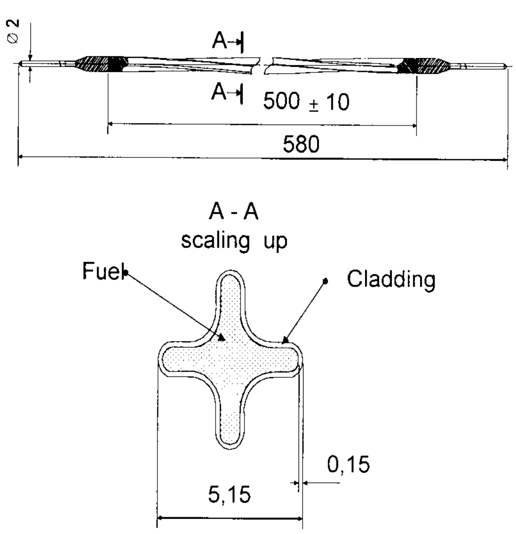

Fig.2 Reactor PIK fuel element

As fuel elements, the crosswise fuel elements in stainless steel clad are used, which are well mastered in production (Fig. 2). In the SM-2 reactor, fuel elements of such type have already been operating many years under the specific maximal load of Q_v = 8 MW/l and more [3]. In the PIK reactor, $Q_{v\,max}$ is at the level of 6 MW/l. Fuel elements are assembled into fuel assemblies of two types (Fig. 3). The core is loaded by 18 fuel assemblies. A central channel is in a neutron trap. The core is cooled by water under the pressure of 5 Mbar and is contained in a double-wall cylindrical vessel made from stainless steel (Fig. 4). Heavy water under the pressure of 1.6 Mbar used to cool the vessel is circulating in the gap between the vessel walls. Originally this gap was also supposed to be used for reactor control by means of a gadolinium nitrite solution in heavy water. A sudden breakage in the strong stainless steel vessel is considered improbable; in an extreme case, the growth of a hypothetical crack could lead to an insignificant leakage of light water from the core into the gap between the vessel walls. Nevertheless, in order to provide additional safety, the use of gadolinium nitrite solution to compensate burning-out has been turned down. It is only possible to use this absorber as an extra system enhancing the negative reactivity of the cooled-down reactor. The control is carried out by means of two absorbing cylinders made from hafnium at the interface with the central trap. The same cylinders are used for emergency shut-down. Eight absorbing plates are situated in the heavy-water reflector, six of which are used for the start-up and two – for emergency shut down (Fig. 1). Emergency shut down in this way is provided by the gap between two hafnium cylinders disposed in the in the vessel and two plates disposed in the heavy water reflector.

The reduction of weight of controls due to the refusal to use gadolinium nitrite solution is overcompensated by the use of a burnable absorber in the form of rods (BAR) [4]. A new PIK fuel assembly with BAR and with replacement of the stainless steel casing material by zirconium alloy is already developed and two experimental assemblies are manufactured. The additional reactivity reserve obtained from the replacement of the casing material is planned to be used for placement of material testing samples for irradiation in the core, including PIK reactor vessel surveillance samples (Fig.3).These material testing fuel assemblies allow the samples irradiation in the fast neutron flux $\Phi \sim 1 \cdot 10^{15}$ n/cm^{2}s (E > 0.7 MeV) [5] at a temperature limited by boiling on its surface (about 270°C).

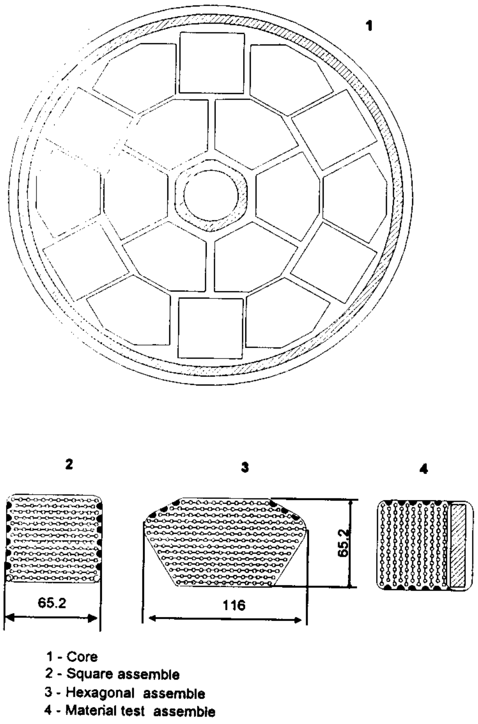

Fig.3. Reactor PIK fuel assemble

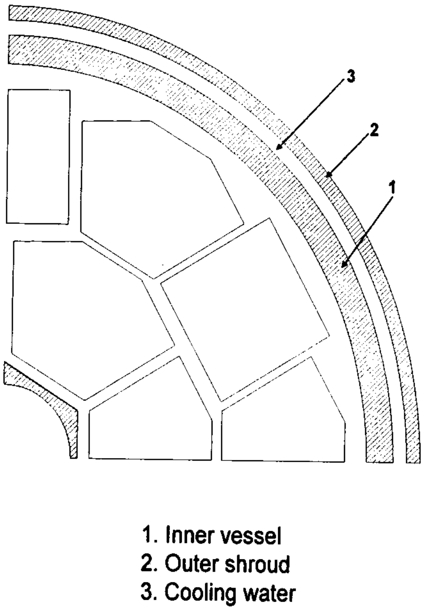

Fig 4. Reactor PIK vessel

The reactor start-up will be implemented on the original fuel assembly design with steel casings and without burnable absorbing rods. This set was purchased by the start-up in 1980s, which did not take place due to changes in the safety requirements for research reactors after the disaster at the Chernobyl Nuclear Power Plant at 1986.

The PIK reactor parameters are given in Tables 1 and 2.

Table 1_**Experimental channel parameters**

Central loop channel in the core CEC	
Thermal neutron flux	$4.5 \cdot 10^{15}$ n/cm^{2}s
Fast neutron flux (E>0.7 MeV)	$7 \cdot 10^{14}$ n/cm^{2}s
Channel diameter	100 mm
Diameter of container for irradiation	40mm
At the pressure of 5 Mbar, the cooling power is	400 kW
Pressure range	$0.15 \div 5$ Mbar
Horizontal channel HEC-10 units	
Thermal neutron fluxes on bottoms	$(0.1 \div 1.2)\ 10^{15}$ n/cm^{2}s
Thermal neutron fluxes at the outlet	$(0.2 \div 3)\ 10^{11}$ n/cm^{2}s
Diameters	$100 \div 250$ mm
Inclined channels I E C – 6 units	
Thermal neutron fluxes on bottoms	$(0.2 \div 1) \cdot 10^{15}$ n/cm^{2}s
Fast flux (E>0.7 MeV) on bottom (IEC5)	$2 \cdot 10^{14}$ n/cm^{2}s
Thermal neutron fluxes at the outlet	$(0.4 \div 2) \cdot 10^{10}$ n/cm^{2}s
Channel diameters	60 – 100 mm
Vertical channels V E C– 7 units	
Thermal neutron fluxes on bottoms	$(1 \div 3)\ 10^{14}$ n/cm^{2}s
Channel diameters	60 mm
Cold neutron sources C N S –2 units	
1. In the vertical channel for the neutron outlet to the neutron guide hall. Average flux value over CNS	$4 \cdot 10^{14}$ n/cm^{2}s
2. In the horizontal channel HEC2 for the ultra-cold neutron outlet Thermal neutron flux	$1.2 \cdot 10^{15}$ n/cm^{2}s
Hot neutron source H N S– 1 unit	
Average thermal neutron flux value	$3 \cdot 10^{14}$ n/cm^{2}s
Wavelength at maximum	0,5Å
Flux at the outlet	$3 \cdot 10^{9}$ n/cm^{2}s
Neutron guides NG – 7 units (with possible growth up to 9)	
Wavelength	$\lambda = 1.0 \div 12$ Å
Outlet fluxes	$(0.3 \div 1.5) \cdot 10^{9}$ n/cm^{2}s

2.Construction status

The construction of the reactor began in 1976. In 1986, the erection of the building was completed and a considerable part of installation work was carried out. The erection of cooling circuits was completed in considerable proportion, the control room was installed and the set-up of control circuits for pumps and gate valves of the intermediate circuit was launched. After the Chernobyl disaster, the requirements for nuclear reactor safety were reviewed in the USSR. The PIK design did not correspond to these requirements and was, to a considerable degree, reviewed.

The reconstruction project has led to significant changes and has doubled the original value.

The most tedious part of the reconstruction is the development of the containment. It has resulted in the necessity for disassembling the building roofing, dismantling all the equipment on two upper floors and slushing the equipment on lower floors.

The changes in the technology are mainly connected with additional safety system redundancy.

In reality, after the disaster at the Chernobyl NPP, construction of the reactor itself was suspended. Initially, a pause in construction occurred due to our search for reconstruction solutions and obtaining the necessary approvals from regulatory bodies. Later on, we experienced problems related to internal containment erection. Finally, government funding was curtailed to a level that was not sufficient for much more than maintaining and conserving what we had already built. Nevertheless, in 1996 an internal containment was created, and building construction was completed, although without internal finishing. In 1999, the three institutions who were interested in reactor development, namely: the Russian Academy of Sciences, the Ministry of Nuclear Energy and the Ministry of Industry, Science and Technologies made a decision to finance the project jointly.

At the present time, reactor vessel, the reflector tank and the iron-water shielding are installed in the reactor vault and the cooling pipelines for the different systems in the vault has been implemented. The neutron beam gates have been installed on the horizontal channels of the reactor. On the primary circulation circuit (PCC), almost all work has been executed and the installation of the system connected with PCC, i.e. safety-related systems is under way.

Out of 485 premises of reactor units, 240 rooms have been handed over for reinstallation and in 80 various purpose rooms the work is finished.

The metal structures for laying out electric cables have been installed and the general power supply cables have been laid out.

3. Construction tactics

The prolonged construction and financial uncertainty in the near future require certain tactics in the work planning. The first start-up line of construction had to be isolated, without the neutron guide hall, physical laboratories and a number of auxiliary facilities. This first line will allow to put reactor critical and limit power growth only up to 100 kW.

If the construction financing was determined years up to the termination, then such a plan would only delay the power start-up of the reactor at the full power of 100 MW. In the circumstances of uncertain financing and the growth of scepticism in the scientific and administrative community, the physical start-up shall contribute to obtaining funds for the completion of the construction. It is impossible to perform physical research planned at the power of 100 kW but this is sufficient for setting up instruments installed on neutron beams and its adjustment.

The completion includes both termination of installation of the technological systems providing the reactor operation at the power of 100 MW and the development of collective use systems for physical research.

The full completion of the construction with the neutron guide hall and the reactor start-up on full power will allow the simultaneously conduction of research at 50 instruments designed for experiments in the field of condensed-state physics, physics of elementary particles, nuclear physics and applied studies.

Table 2. **PIK reactor parameters**

Power	100 MW
Maximal specific power	6 MW/l
Core volume	50 l
Core diameter/height	390 mm/500 mm
Fuel elements of the PIK type	
-	Enrichment 90%
-	Fuel UO_2 in the copper-beryllium matrix
-	Uranium density in the matrix 1.5 g/cm^3
-	Cladding: stainless steel with the thickness of 0.16 mm
-	core fuel concentration by uranium-235 – 600 g/l
Reflector D_2O	
Diameter/height	- 2.5 m/2m
Cooling circuit	
Coolant	- H_2O
Pressure	- 5 Mbar
Flow-rate	- 2400 m^3/hour
Inlet/Outlet temperature	- 50/95°C

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