Table

Criterion of safety	99.87/99.9	99.87/95	99.9/50	95/95
Probability of emergency	$1.3 \cdot 10^{-3}$	$1.3 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$5 \cdot 10^{-2}$
Restriction on amplitude of a deviation of initial parameters from rating values, expressed in σ units	3σ	2σ	0.7σ	2σ
Maximally - permissible reactor power, MW	118.6	126.9	139.7	135.3

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THE USING OF LIQUID REGULATOR SYSTEM IN SUB-CRITICAL REGIMES OF PIK REACTOR

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Layout peculiarity of the PIK research reactor [1] and its control system is the system of two absorbing shutters arranged around the neutron trap. The 8 regulators in the heavy-water reflector are used only in the reactor start-up and as scram rods. Their effectiveness is $4.5\beta_{eff}$. One shutter effectiveness is about $4.5\beta_{eff}$, therefore the analysis of event: "one the most hard regulator failure" is the important part of the design safety validation. In the beginning of reactor lifetime this failure leads to the $1\beta_{eff}$ [2] reactor sub-criticality after the shut-down in the most unfavorable moment of the reactor lifetime. It's necessary that during the failure effect liquidation the sub-criticality after cock emergency protection corresponds to normative value 1%. For that the additional liquid regulator system (LR) is used. Absorber (gadolinium nitrates - $Gd(NO_3)_3$) is dissolved in the heavy water and introduced in the gap between two vessel barrels at the boundary between the core and the heavy water reflector. In ordinary situation this system isn't used. D_2O circulation circuit cools the reactor vessel, absorber is inserted during the time of mechanical regulator failure. The same system can be used for 1% reactivity worth before beginning of lifetime and for the "cold" reactor start-up realization from the sub-criticality. The inlet in the critical state and power raising carried out subsequently due to mechanical regulators.

On the physical model of the reactor PIK [1] it was investigated the reactivity effects versus $Gd(NO_3)_3$ concentration in the aqueous solution filled the reactor vessel gap for different position of the reactor regulatory bodies (see Fig.).

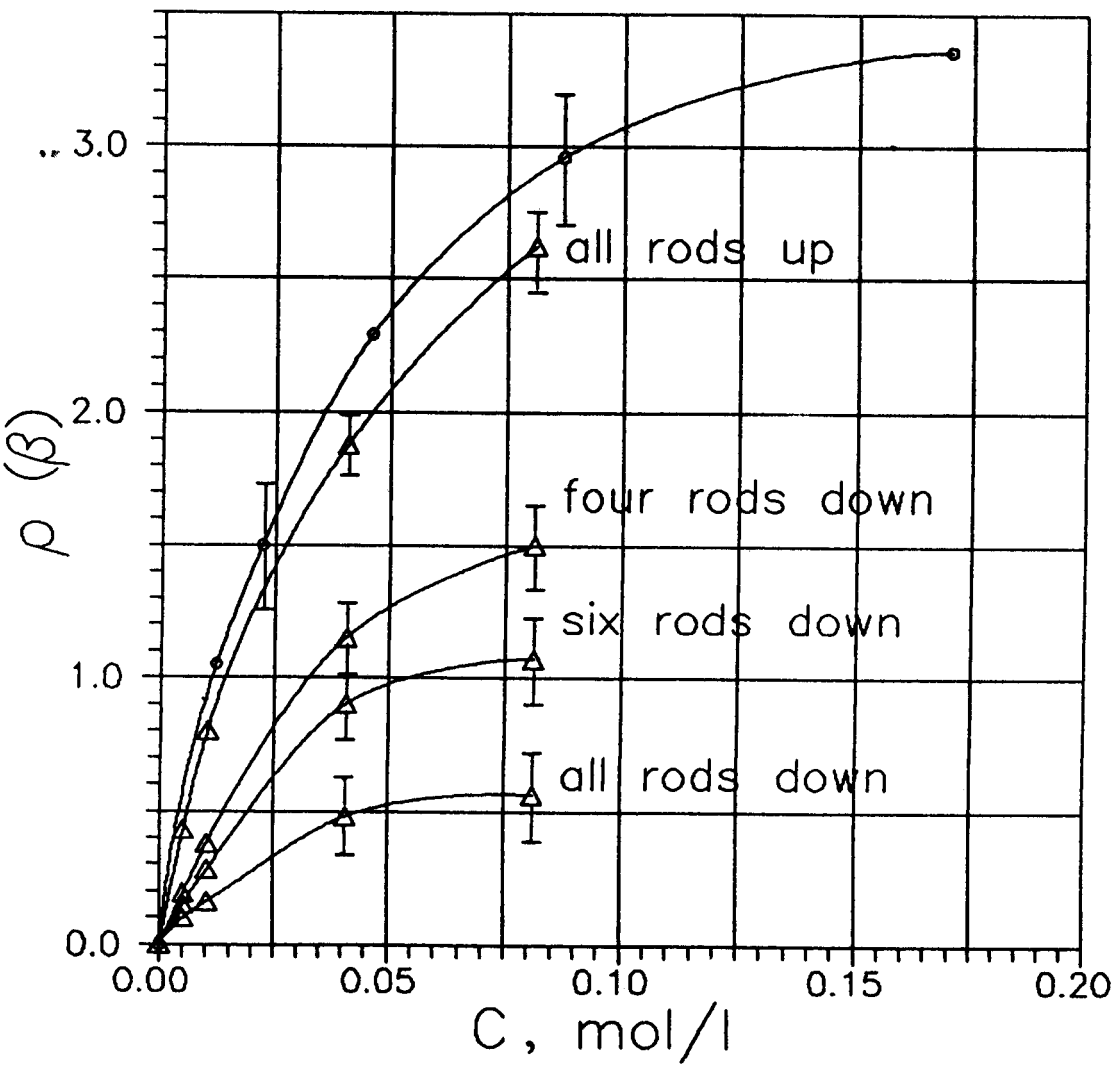

Fig. Reactivity effects of $Gd(NO_3)_3$ aquatic solution vs $Gd(NO_3)_3$ concentration in PIK reactor. ⊙ — $Gd(NO_3)_3$ in H_2O, △ — $Gd(NO3)_3$ in D_2O

Reactivity effect decreases due to increasing of introduced rods quantity. It's determined that in case with six shim rods and two scram rods in the beginning of lifetime with $Gd(NO_3)_3$ concentration of 0.08 mole/l the effect is composed $(1.05 \pm 0.16)\beta_{eff}$ and satisfied to the condition of limitation of this effect by normative value no more than 1% correspondingly with the system function during the time start-up.

The using LR system as the reserve safe system allows to increase reactor sub-criticality on $0.5\beta_{eff}$ when any regulator failure and to decrease the limitations of permissible reactivity margin connected with necessarity to take into account the possibility of such failure.

The using LR system as start-up regulator allows to increase reactivity margin for fuel burnup and lifetime duration on 30%.

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ADVANCED IRRADIATION OF THE CAB-1 MATERIAL IN THE WWR-M REACTOR

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Introduction

Questions of safe exploitation of nuclear reactor structure elements are connected with radiation damage of the structural materials due to reactor radiation effects. Therefore it's important beforehand to foresee the rate and character of materials mechanical properties changes under irradiation with a glance to concrete exploitation conditions.

The WWR-M reactor operated from December 1959. During 35 years (to January 1, 1996) its energy generation reached $\simeq$ 70 GW·days what is $2 \div 4$ times more than the energy generation of same type reactors working in Russia and abroad.

The maximum fluence of neutrons with energy above 0.8 MeV on bottom of central channels which are a part of vessel is equal to $1.6 \cdot 10^{22}$ n/cm^2 (to January 1, 1996). For vessel working resources forecasting it's necessary the data of mechanical properties CAB-1 material changing at neutron fluence with the energy above 0.8 MeV $> 1.6 \cdot 10^{22}$ n/cm^2. More higher fluence was received on the control and protection system channels (CPS) worked in middle part of active core during 22 years ($1968 \div 1990$). One of them was used for samples making and measurements of CAB-1 alloys mechanical properties.

CPS channels with diameter 35 mm from the CAB-1 alloy have stainless steel insert of 200 mm height in middle part of the active core. Under drawal of the control rod stainless steel insert acts as grey screen decreasing the thermal flux and energy generation in neighbouring fuel element.