USE OF SEPARATED SHUTTERS DRIVES FOR PIK REACTOR

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Upper and lower shutters are arranged in a central lihgt-water neutron trap at a boundary between a fuel and a moderator and are a main control element. Summary shutters weight is 9.5 β_{eff}. In a starting design there was a hard mechanical bond between the upper and lower shutters which ensured their synchronous motion relatively to the middle of the active core. For the shift of two shutters one actuator was used. The shutters combine functions of emergency protection, of the automatic regulator and of a burn-up compensator. Weight of the lateral rods situated in the heavy-water reflector is less than the shutters weight. Their summary weight is 4.5 β_{eff} in the beginning of the lifetime and decreases to 3.4 β_{eff} after the shutter driving. These rods are placed well above the fuel level after the reactor power-up (Fig.1). Using them as emergency protection is less effective in comparison with regulators in an active core due to additional time of flight from the initial position to the active core. Using shutters as emergency protection decreases dead time from emergency shutdown signal to the beginning of negative reactivity introduction from 1.3 to 0.35 s in the most unfavorable case.

During the reactor operation the shutters shift and compensate reactivity effects due to ^{135}Xe accumulation, active core heating and fuel burn-out. To justify the design safety it is necessary to take into account failure of the most effective regulator. In the initial design the failure of the actuator (shutter sticking in a moving apart position) which is accompanied by the depoisoning and cooling down, leads to overshoot of positive reactivity after the reactor shutdown. The overshoot of positive reactivity in the part of the lifetime can not be compensated by another mechanical control system, namely by the rods in the reflector.

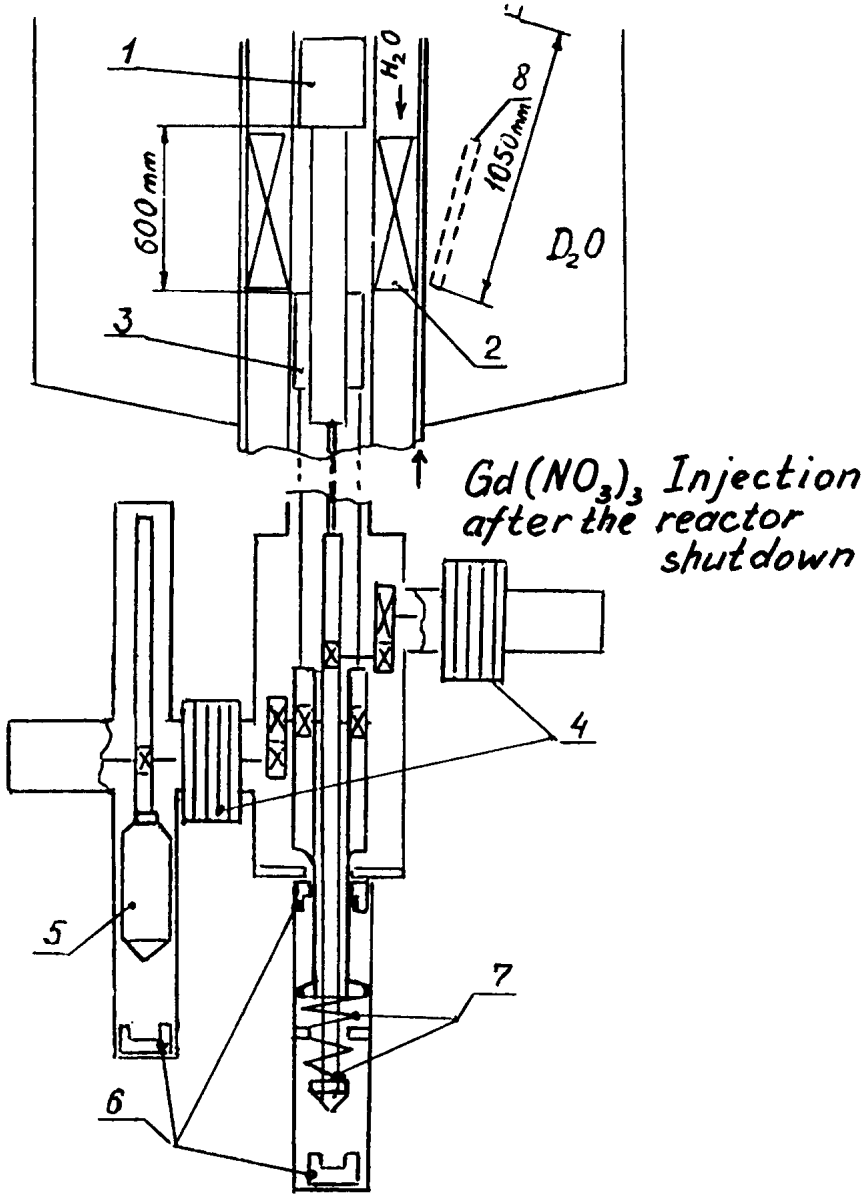

Fig.1. Device with two independent drives:
1 — upper absorber cylinder (shutter); 2 — core; 3 — lower absorber cylinder; 4 — engine; 5 — counterweight; 6 — hydraulic brake; 7 — spring; 8 — absorber rod

The shutters work in the automatic control system and its shift is constantly controled, so that the probability of its jamming is low. Therefore in the initial design it was allowed to prevent the overshoot of positive reactivity by unloading or by D_2O pouring out. It was a shortage of this design. The problem was to eliminate this effect by means of an emergency protection system.

For that purpose and to improve the fast-acting of the emergency protection in the case of one regulator failure the separate drives for shutters motion were proposed. The additionals of the disposal of one shutter with a good mechanism depend on the initial position of the shutters and on the interaction between them. Experimental and calculated ratios of the effectivity of one shutter disposal in abnormal mode to the total effectivity of two shutters disposal in normal mode are given in Fig.2. An interference between two absorbers is small: it is within the range of 8 per cent from the total weight of the shutters. Total effectivity

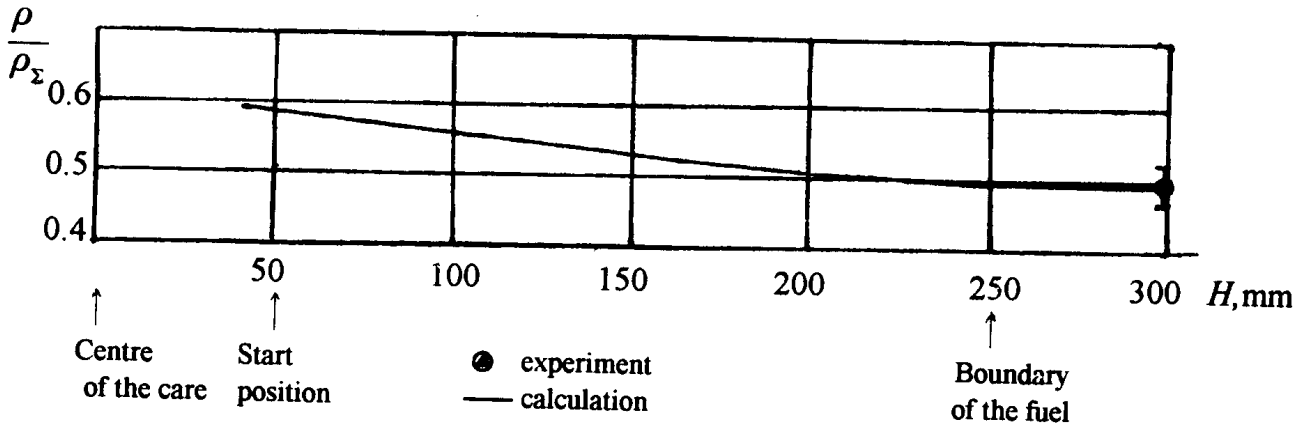

Fig.2. Relative reactivity after reacor shutdown with failure of one drive: ρ — reactivity insertion by one absorber; ρ_Σ — total reactivity insertion by two absorbers; H — distance between centre of core and end of absorber

of the system of two shutters in safety analysis can be calculated as the sum of those of the separate shutters. Using separate drives the failure of one of them does not lay obstacles to another. In this case the total effectivity of the safety rods and of one shutter will be enough for reactivity overshoot compensation after reactor shutdown at any moment of the lifetime. Analysis showed that less favourable situation appears in the lifetime beginning when the shutters are pulled apart for 200 mm, but even in that case the negative reactivity about 1 β_{eff} is provided. Futher shutters pulling caused by the burn-up is less dangerous since the burn-up effect does not change sign and effectivity of the shutter which is in a good repair increased. It is possible to increase the negative reactivity using delivery of a liquid absorber to the liquid regulator as an additional protection in the shutdown reactor.

When designing the actuator the principle of the upper shutter insertion under its own weight was used. The counterweight and the returning spring are used to return the lower shutter to the active core. It provides necessary fast-acting and satisfactory tractive efforts of the pitch engine. The use of the early equipment development is provided to a maximal degree.