A Bare Critical Assembly of Natural Uranium and Heavy Water

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The first reactor built in Yugoslavia was the bare zero energy heavy water and natural uranium assembly at the Boris Kidrič Institute of Nuclear Sciences, Belgrade. The reactor went critical on April 29, 1958.

The possession of four tons of natural uranium metal and the temporary availability of seven tons of heavy water encouraged the staff of the Institute to build a critical assembly. A critical assembly was chosen, rather than a higher flux reactor, because the heavy water was available only temporarily. Besides, a 10 Mw, enriched uranium, research reactor is being built at the same Institute and should be ready for operation late this year.

It was supposed that the zero energy reactor would be a very useful tool which would provide experience in carrying out critical experiments, operational experience with nuclear reactors, and the possibility for an extensive program in reactor physics.

DESCRIPTION OF THE REACTOR

The critical assembly built is completely nonreflected as seen in Fig. 1. The bare assembly was chosen in order to achieve: (1) simplest geometry and, hence, easy interpretation of experimental results; (2) precise determination of the value of the buckling for such a reactor and (3) constructional simplicity and experimental feasibility for any changes in the reactor.

In order to achieve a completely nonreflected system the reactor core is placed on a platform 4 m above the floor. The aluminium rack which supports the platform is designed for 15 tons weight. A separate aluminium rack is built around the reactor to support a two-floor platform for the operating personnel. This rack, with the platforms, can be easily removed if necessary.

The reactor tank is at least 4 meters away from any reflecting surfaces, walls, floor and roof. The rack which supports the reactor is placed in the center of a pool 8×8 m in area and 1.5 m deep. The pool was built because of constructional convenience but serves at the same time as an emergency pool for heavy water.

Figure 2 is a diagram of the reactor. In a separate room below the floor is the 7 m^3 storage tank for heavy water (3). A canned rotor pump (4) is used to pump heavy water into the reactor tank (1). Pneumatic valves (6) are used to control the flow of heavy water into or out of the reactor tank. The valves (7) are used to regulate the passage of air through the tube which connects the air spaces above the heavy water in the reactor and storage tank.

The valves (5) connect the system to the drying unit used to evaporate the heavy water left in the reactor tank. The unit consists of a closed circulation system in which the air from the tank is pumped through a cold trap, then heated prior to injection back to the tank.

THE REACTOR CONTROL

The control of the reactor reactivity is performed by the change of the heavy water level. The reason for this system is to avoid the disturbance of the geometry which a control rod would introduce. The pneumatic valves that regulate the heavy water flow are controlled by magnetic valves in the compressed air flow system. A canned rotor centrifugal pump (two

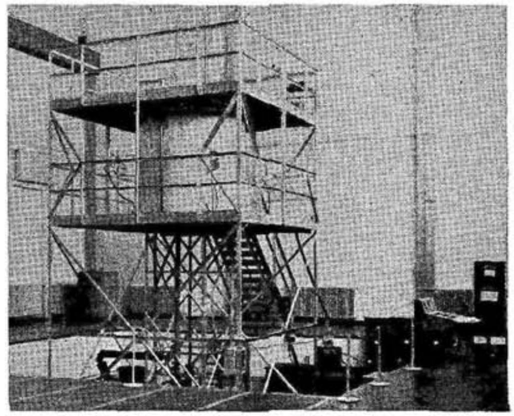

Figure 1. View of the zero energy reactor

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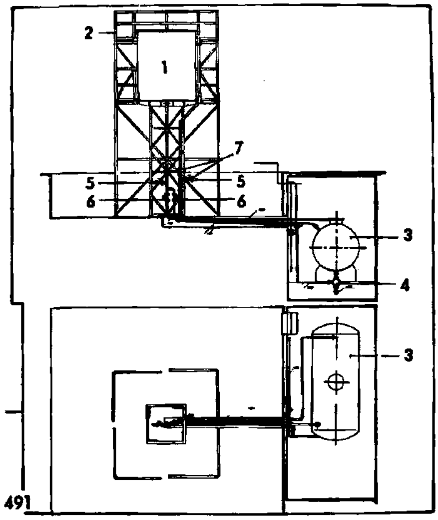

Figure 2. Elevation and plan view of the reactor; (1) The reactor tank, (2) the platform rack, (3) the storage tank, (4) the pump, (5) the valves connecting the drying unit, (6) the heavy water valves, (7) the air valves

speed) is used to pump the heavy water. The two speeds permit the heavy water level in the reactor tank to be changed at an average rate of 2.5 cm/min or 0.8 cm/min. The higher rate is used for filling the reactor tack and the lower for small changes of heavy water level round the critical point. Since the reactivity of the reactor round the critical level changes by 1.5% per cm of the heavy water height, the rate of change of the reactivity while the water is pumped in is 1.2% per min. This is sufficiently low for safe operation. Two speeds for lowering the water level are also available: 11 cm/min and 1.7 cm/min.

The water level is measured by means of electrical contact between the heavy water surface and the calibrated point probe. This ensures no disturbance of the geometry by the level meter and gives an accuracy of 0.2 mm.

Two cadmium safety rods, acting by gravity, are provided. The magnetic release of the safety rods can be performed either manually or automatically at a prescribed neutron flux level.

The temperature of the heavy water is measured with a platinum resistance thermometer which can be moved to any place of the reactor.

The neutron flux is measured with three BF_3 counters of various sensitivities. They are placed round the reactor on the first operational platform as shown in Fig. 1. Each of the neutron counters has separate counting equipment consisting of a preamplifier, a linear amplifier, a scaler, a 5-decade logarithmic ratemeter, a linear ratemeter and a recorder.

Separate sets of counting equipment are used for measuring the slow and fast neutron fluxes, both for experimental purposes and for radiation dosimetry.

Table 1

Inside diameter of the reactor tank	199.86	cm
Aluminium tank wall thickness	1.0	cm
Max. heavy water height	210	cm
Length of uranium bars	210	cm
Diameter of the uranium bars	2.5	cm
Thickness of the aluminum canning	0.1	cm
Lattice pitch	12	cm

THE REACTOR CORE

The first core built in the reactor consists of heavy water as moderator and natural uranium metal as fuel. Figure 3 shows the cross section through the reactor core. The aluminium reactor tank (1) is tightly closed by the aluminium cover (2) on which a small plate (3) covers a slot along the diameter of the tank. Uranium slugs (6) are supported on the bottom of the tank, entering holes on the bottom plate (4) which fix the distance between the rods. Another grid plate (5) is placed near the top of the reactor tank. By supporting the uranium slugs on the bottom of the tank, an effective, simple geometry was insured.

On the slot cover (3) is situated all the control equipment: level meter (7), safety rods (9) and source injector (8).

The dimensions of the core are shown in Table 1.

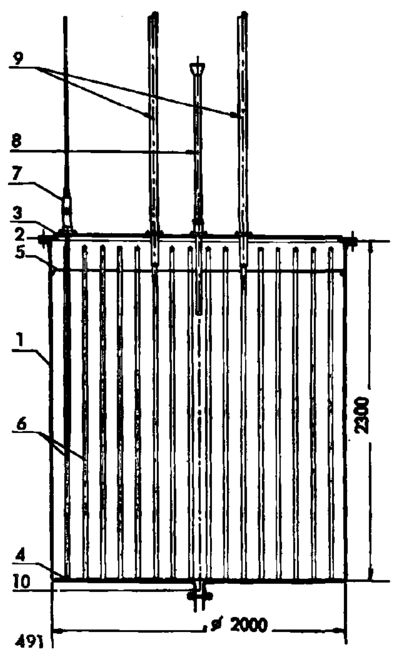

Figure 3. The cross section through the reactor core; (1) The reactor tank, (2) the cover of the tank, (3) the slot cover, (4) the lower grid plate, (5) the upper grid plate, (6) the uranium slugs, (7) the level meter, (8) the source injector, (9) the safety rods, and (10) the heavy water in and outlet

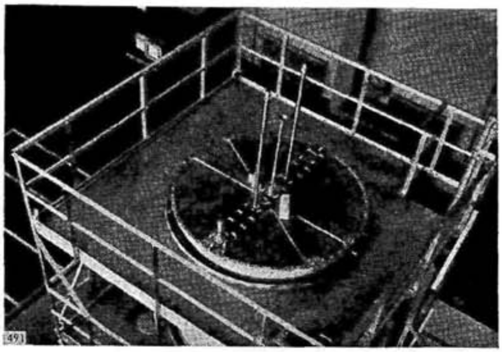

Figure 4. Top view of the reactor

Figure 4 shows the top of the reactor tank where the slot cover can be seen. On it (from left to right) are the level meter probe, first safety rod, the neutron source injector and the second safety rod.

FIRST EXPERIMENTAL RESULTS

The reactor went critical at a heavy water level of 177.15 ± 0.1 cm, at a temperature of 22°C. Since the average radius of the tank is 99.93 ± 0.1 cm the geometrical buckling for this system, taking into account the extrapolation length of 1.75 cm, is

$$B^2 = 8.618 \pm 0.014 \text{ m}^{-2}.$$

The approach to criticality was performed with a Ra–Be neutron source of 500 mc radium which could be lowered as far as the surface of the heavy water. The critical level was taken as the one at which the removal of the source did not affect the neutron count rate. Actually the presence of spontaneous fission neutrons from the uranium gives a small rise of the neutron level at the critcal point that introduces an error in the exact determination of the critical level. The total error in the determination of the critical heavy water height, taking into account the imperfection of the reactor tank and the error of the level meter was estimated to be 0.1 cm.

By approaching fast to criticality and by inserting the safety rods occasionally to reduce the total neutron level, it was possible to reach the critical point with a very low radiation level round the reactor. With the neutron source above the reactor core the radiation level found in the pool, where the control instruments are placed, were the following:

Gamma radiation	5 mr/h
Fast neutrons	5 n/cm^2. sec
Slow neutrons	2500 n/cm^2. sec

It was shown, therefore, that this reactor, although completely unprotected, could have been used up to the critical point and even over critical with a period of a few minutes without endangering the personnel round the reactor.

An underground control room has been built so that even higher excursions of reactor reactivity may be made.