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ZERO ENERGY REACTOR „RB“

by

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In 1958 the zero energy reactor „RB“ was built with the purpose of enabling critical experiments with various reactor systems to be carried out.

The first core assembly built in the reactor consists of heavy water as moderator and natural auranium metal as fuel. In order to be able to obtain very accurate results when measuring the main characteristics of the assembly the reactor was built as a completely bare system.

Introduction

In accordance with the nuclear reactor developement programme of the Institute of Nuclear Scinces „Boris Kidrič“ in Vinča a zero energy reactor was built in 1958.

The purpose of this zero energy reactor is to provide a tool for carriyng out critical experiments with various reactor systems.

The temporary disposal of seven tons of heavy water and the possibility of constructing a heavy water-natural uranium critical assembly and immediately carriyng out critical experiments encouraged the building of the zero energy reactor.

The first critical assembly of natural uranium and heavy water is intended to provide:

— experience in carriyng out critical experiments
— operational experience with nuclear reactors
— highly accurate critical conditions for heavy water-natural uranium lattices.

In order to meet the third requirement it was decided to build a bare assembly which would enable very straightforward measurements of the buckling values and other constants of the lattices, making them easily comparable with theoretical results.

General description of the reactor

In order to achieve a completely non-reflected system, the reactor tank is mounted on a platform which is at least four meters away from any reflecting surface (walls, roof, floor). In this way the reflection of neutrons back to the reactor tank has been reduced to less than 4‰. The aluminium structure supporting the reactor platform is designed for a weight of 15 tons. Two additional platforms are built around the reactor for the operating personnel. This two platforms are supported by a separate structure in order to prevent any oscillation of the reactor tank while the personnel is moving on the platforms, and also to make possible the removal of the platforms, should any material around the reactor be objectionable.

The supporting structure of the reactor is placed in the center of a basin which is 8 by 8 sq. meters large and 1.5 meters deep. The basin was built because of constructional convenience but serves, at the same time, as an emergency pool for heavy water.

Fig. 1 shows the general view of the zero energy reactor.

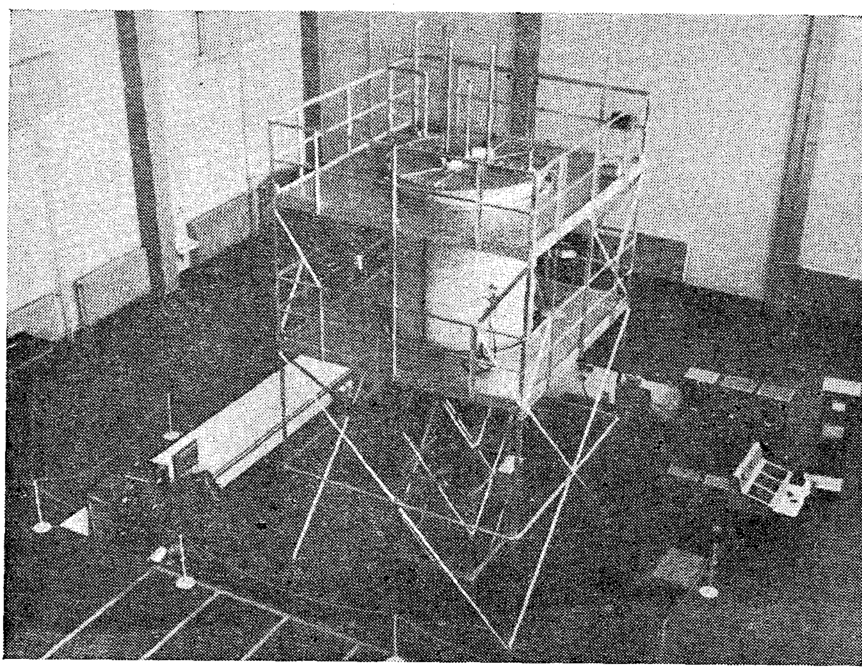

Fig. 1. — General view of the reactor

The reactor core

The first core assembly build in the reactor consists of heavy water as moderator and natural uranium metal as fuel. The uranium slugs of 2.5

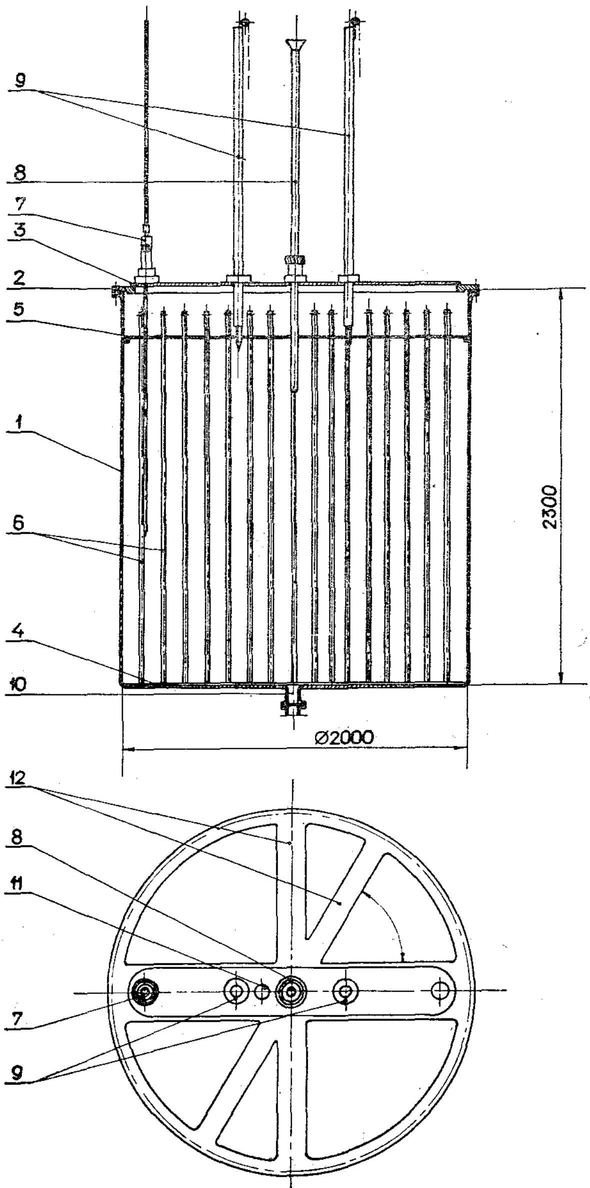

Fig. 2. — Reactor tank

cm. diameter are canned in 99.9% pure aluminium. The canning is 1 mm. thick.

Fig. 2 shows the cross section of the reactor core. The reactor tank (1) made of 10 mm. thick aluminium is tightly covered by an aluminium lid (2) which is strengthened by radial ridges (12). The reactor lid has a 7 cm. wide slot along the diameter which serves for neutron distribution measurements. The slot is closed with a special cover (3) on which is mounted the control equipment: level meter (7), source injector (8), two safety rods (9) and two small windows (11).

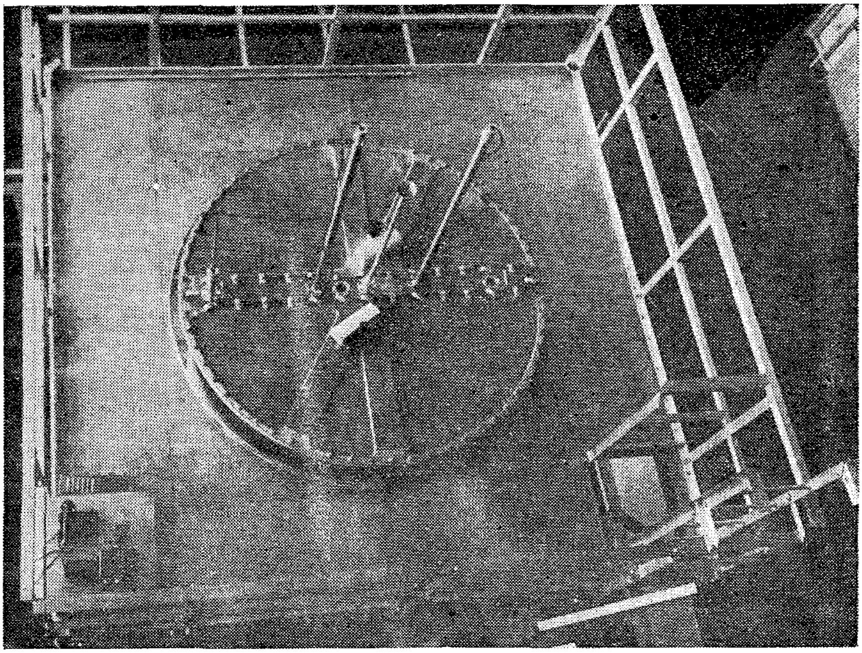

Fig. 3. — Top view of the reactor

The uranium slugs (6) rest on the botton of the tank and the distance between them if fixed by two grid plates (4 and 5), one of which is placed near the top and the other at the bottom of the reaktor tank. By supporting the uranium slugs from the bottom of the tank good and simple geometry of the system is ensured.

Heavy water inlet and outlet are at the bottom of the tank (10).

The dimensions of the core are as follows:

Inside diameter of the reactor tank (average)	199,86 cm
Aluminium tank wall thickness	1.00 cm
Max. heavy water level	208.00 cm
Lenght of uranium slugs	210.00 cm
Diameter of uranium bars	2.5 cm

Aluminium canning thickness	1.0 cm
Lattice pitch (square)	12.0 cm
Total weight of uranium	3,995.0 kg
Total volume of heavy water	6.36 m^3

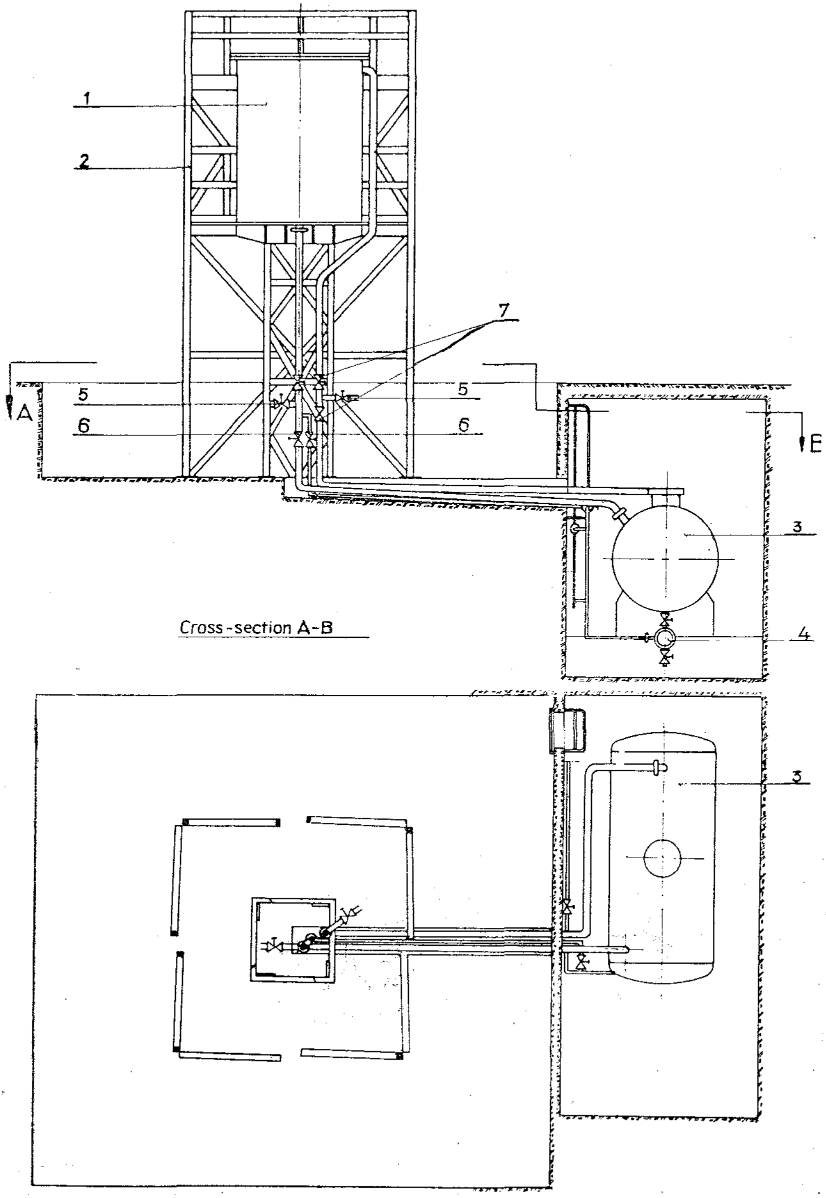

Fig. 4. — Schematic view of the reactor

Fig. 3 shows the top view of the reactor tank. The level meter probe, the first safety rod, the neutron source injector and the second safety rod can be seen on the slot cover looking from left to right.

Heavy water circulation system

Heavy water circulates through stainless steel tubes, one inch in diameter for pumping up heavy water into the reactor tank and two inches in diameter for dropping the water back into the stogare tank.

Fig. 4 shows the schematic diagram of the reactor. The reactor tank (1) is connected with the storage tank of heavy water by a system of tubes. The storage tank of 7 m³ capacity is situated in a separate room below the

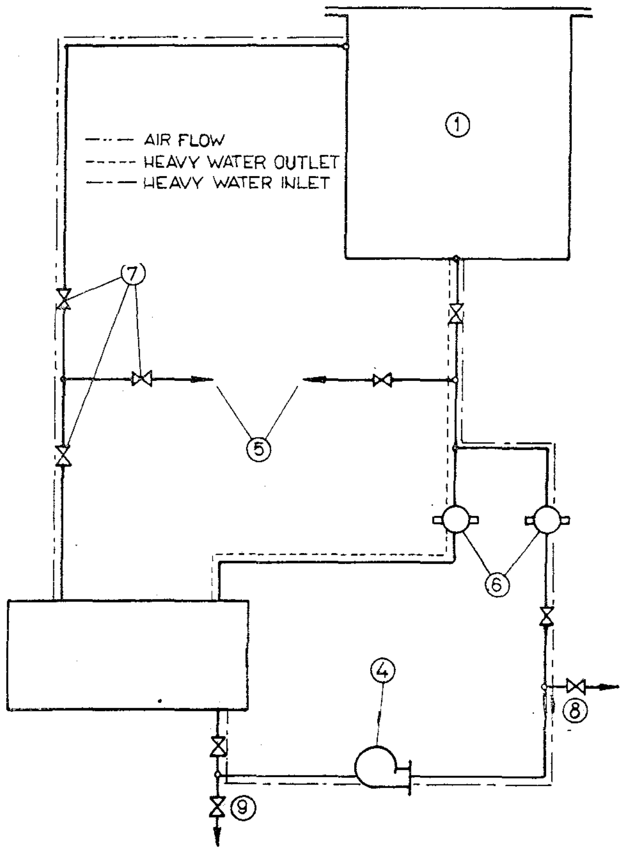

Fig. 5. — Heavy water circulation loop

main floor. A canned rotor pump (4) is used to pump the heavy water into the reactor tank. From the reactor tank heavy water flows down to the storage tank by gravity.

Valves (5) connect the system with the drying unit which dries off heavy water in the reactor or storage tank. The unit consists of a closed circulation system in which the air from the tank is pumped through a cold trap and heated to 60° C prior to injection back into the tank.

The flow of heavy water when pumped into the reactor tank or poured from the reactor tank down to the storage tank is shown in Fig. 5. Vavles (8 and 9) establish connection with other systems.

Reactor control

The reactivity of the reactor is controlled by changing the heavy water level, which is performed by pumping heavy water into the reactor tank to increase the reactor height, and by letting heavy water flow down to the storage tank by gravity to decrease the height.

The use of heavy water level change as a means of controlling the reactivity has obviated the necessity of control rods which would disturbe the nuclear geometry of the system.

Pneumatic valves which regulate the heavy water flow are controlled by magnetic valves in the compressed air flow system.

The canned rotor centrifugal pump used for pumping heavy water can be run at two speeds. The two speeds permit the heavy water level in the reactor tank to be increased at an average rate of 2.5 cm/min and 0 8 cm/min respectively. The higher rate is used for filling the reactor tank and the lower one for small changes of the heavy water level about the critical value.

Since the reactivity of the reactor near the critical level changes by 1.5‰ per cm of the heavy water level, the rate of increase of reactivity while the water is being pumped is 1.2‰ per minute which is sufficiently low for safe operation.

Two speeds of lowering the water level are also available: 11 cm/min and 1.7 cm/min.

The water level is measured by means of a calibrated point probe which, when in contact with the heavy water surface, closes the electrical circuit in series with an indicating instrument. In this way it is ensured that the level meter will not disturbe the nuclear geometry and an accuracy of 0.2 mm is achieved. The level indicating instrument shows only that electrical contact between the heavy water surface and the probe has been established, but if the level continues to increase the deflection of the indicating instrument will also increase.

Temperature of the heavy water is measured by a platinum resistance thermometer connected in a Wheatstone bridge. The thermometer can be placed in any position inside the reactor tank.

The neutron flux is indicated by three neutron BF^3 proportional counters of various sensitivity. They are placed around the reactor on the first operational platform as seen in Fig. 1. Each of the neutron counters has a separate counting equipment consisting of a preamplifier, a liniear amplifier, a scaler and a five decade logarithmic ratemeter. A selector switch connects all three ratements to a recorder which provides permanent records of the neutron flux variation

A special electronic timer activating the scalers for a prescribed period in prescribed intervals is also provided for measuring the time dependence of the neutron flux

Safety system

The safety system of the reactor consists of the following components:

1. Control key
2. Safety rods
3. Alarm dose ratemeters
4. Automatic shut down

The control key is used to give electrical contact to the main switch of the control system. When the key is out the cadmium safety rods drop into the reactor and the pumping of heavy water is prevented. The key has to ensure that the responsible person has undertaken the necessary inspection prior to reactor start-up.

The reactor is provided with two cadmium safety rods mounted on top of the reactor as seen in Fig. 2 and 3. The rods, which are 50 cm long and 3 cm in diameter are placed along the diameter of the reactor at a distance of 30 cm from the center of the reactor, and have separate driving systems. Each one is able to shut off the reactor even at the maximum heavy water level. They are kept in the upper position by means of electromagnets and fall into the reactor by gravity when the current in the electromagnets is cut off. The fall is damped by spring-type shock absorbers mounted in the driving mechanisms.

The reactor can be shut down manually by pressing the scram button on the control panel or automatically after a prescribed neutron flux level is exceeded. Automatic shut down is initiated by a relay-type scramming circuit connected in series with the limit switch of the neutron flux recorder, but no interlock is provided to prevent the reactor from being started unless the recorder is switched on.

The radiation monitoring equipment consists of fixed instruments indicating the slow and the fast neutron flux as well as the intensity of gamma radiation. Audible signals are provided to warn the personnel and the gamma dose rate, to which they are exposed, has exceeded a prescribed level.

Approach to criticality

In order to determine safely the critical conditions of the system the approach to criticality is cautiously followed. The heavy water level is gradually increased and the subcritical steady state neotron level is registered. In order to obtain a high neutron counting rate a 500 mC Ra-Be neutron source is used. The source can be injected to any position along the axis of the reactor. The increase of the flux with time is followed and when the counting rate of the neutron detector is stabilised, the neutron flux is registered. The stabilised neutron flux level increases with the increase of the heavy water level (increase of the multiplication factor) becoming infinite when the reactor becomes critical. At the same time the period and hence the time of stabilisation also increase, becoming of the order of hours near the critical level.

Removal of the neutron source causes the neutron flux level to decrease with a period which increases with the heavy water level, becoming infinite at the critical point. Hence, the neutron flux level at the critical point is not affected by the removal of the neutron source. In this way the critical heavy water level is determined with an accuracy of 0.5 mm.

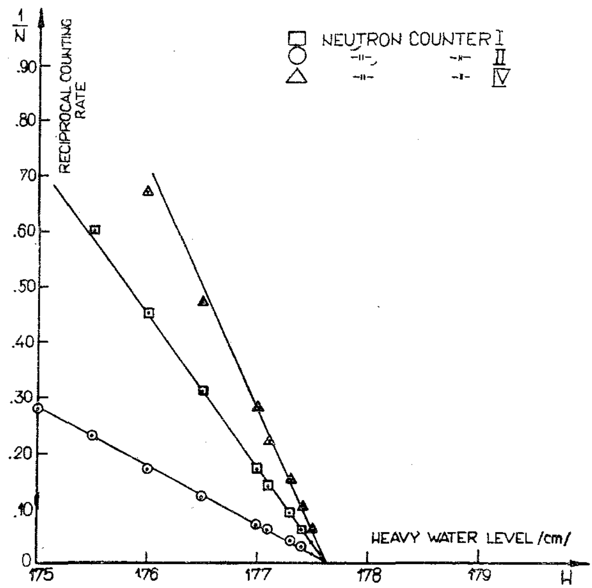

Fig. 6. — Approach to criticality diagram

In order to predict the critical level, the inverse values of the stabilised neutron flux intensity are plotted against the heavy water level (Fig. 6). The inverse value of the stabilised neutron flux decreases with the increase of the heavy water level tending to zero at the critical point where the neutron flux diverges.

The reactor went critical at the heavy water level of 177.60$\pm$0.1 cm at the temperature of 22° C.

The reactor can be brought to an overcritical state by a further increase in the heavy water level, but in the meantime, the reactor should be shut down by means of the cadmium rods in order to reduce the general level of the neutron flux. By lifting the cadmium rods the reactor is brought fast back to criticality. In this way even periods of about 10 seconds were attained while the radiation around the reactor did not exceed the permissible level.

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