THE PROJECT OF THE NEW RESEARCH REACTOR FRM-II AT MUNICH

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ABSTRACT

A new national research reactor is planned in Germany which shall replace the existing FRM reactor at Garching. The new FRM-II will be optimized primarily with respect to beam tube applications but it will also allow the irradiation of samples etc.. Because of the "compact core reactor concept", which provides for a particularly small H_2O cooled reactor core in the center of a large D_2O moderator tank, high values of the thermal neutron flux can be obtained at only 20 MW power. This paper also discusses some of the features of the technical concepts of the new reactor.

INTRODUCTION

The existing research reactor FRM of the Technical University of Munich at Garching - a conventional swimming pool reactor of 4 MW power - has become more than 30 years old now. Plans to modernize it or - finally - to completely replace it with a new one have been made for years. As a result of this design effort the so called "compact core reactor concept" has been developed which will be discussed in the next section of this paper. The new research reactor FRM-II is considered to become the main national neutron source of the coming decades. It is being designed as a high performance but nevertheless relatively small reactor - as may also be deduced by realizing the distinction between a national and an international project in Europe.

The scientific case has been often discussed in Germany during the last couple of years and strong support has always been obtained from the German scientific community and refereeing institutions. Recently further progress has also been achieved on the political level with respect to the funding of the project. At present we are working on the conceptual design and on the safety report of the facility.

COMPACT CORE REACTOR CONCEPT

The new neutron source shall be optimized primarily with respect to beam tube applications. That is, high flux levels and pure spectra of thermal neutrons have to be provided in a large useable volume outside of the core. All this has to be achieved at a relatively small value of the reactor power which has been established to be 20 MW. So our design studies have led to the concept of a particularly small reactor core cooled by light water and situated in the center of a large heavy water moderator tank /1,2/.

This "compact core" consists of a single, cylindrical fuel element with 113 fuel plates which have the shape of involutes. The inner and outer diameters of the two aluminum core tubes ("side plates") are 118 and 243 mm, respectively, and the active height of the fuel plates is 700 mm. The light water of the primary cooling circuit flows at a velocity of 17.5 m/s downwards through the cooling channels - which are 2.2 mm wide - between the plates. The full excess reactivity of the core will be controlled by a single hafnium absorber cylinder (with an aluminum filler) which moves upwards in the inner core tube during the cycle and which is followed by a beryllium inner moderator. A long, vertical core channel tube separates the core and its H_2O cooling circuit from the surrounding moderator tank which contains heavy water and which has dimensions of 2500 mm both in diameter and height.
In addition to all the experimental installations five safety shutdown rods are provided for in the D_2O tank which are, however, fully withdrawn during normal reactor operation. The D_2O tank with the core and all the equipment is placed in the center of the reactor pool containing light water.

The design value of the reactor cycle length is 45 - 50 days. In order to obtain the necessary excess reactivity with such a small core, high enriched uranium (93%) will be used in combination with the new high density U_3Si_2-Al dispersion fuel. With an active volume of only 17.6 liter the average power density in the compact core is 1.15 MW/liter. The power density profile in the core will be flattened radially by choosing an uranium density in the fuel of 3.0 g/cm^3 within a radius of 105.6 mm and of only 1.5 g/cm^3 outside of it. Axially the same goal will be achieved by installing a ring of boron burnable poison in the outer core tube just underneath of the edge of the fuel plates. In this way the maximum value of the heat flux density from the plates into the water can be kept below about 500 W/cm^2.

For the unperturbed case, i.e. for the moderator tank containing D_2O only and nothing else, neutron transport calculations have yielded a maximum of the thermal neutron flux of about 8 x 10^{14} $cm^{-2}s^{-1}$ in the D_2O at 20 MW power. The corresponding ratio of flux outside of the core to power ("rendement") is higher than at any other reactor /1,2/. The experimental installations to be realized in the moderator tank include, first of all, 11 big horizontal beam tubes. They all have directions tangential to the core in order to suppress background radiation, and some of them will be connected with a cold or a hot neutron source. However, although first priority will be clearly given to the beam tube applications, the new FRM-II will generally be a multipurpose reactor. That is, it will also provide for a variety of vertical channels for the irradiation of samples and also for a secondary fission target ("converter") to produce high energy neutrons for medical and computer tomography applications.

FEATURES OF THE PLANT DESIGN

A schematic vertical cut through the reactor pool with part of the equipment is shown in Fig. 1 /3/. The compact core (#1) is placed in the core channel tube which leads through the center of the D_2O moderator tank (#12). The central control rod with its hafnium absorber (#2) and its beryllium follower underneath is shown in its shutdown position. It can be moved upwards by the drive mechanism (#4) but can also be released quickly by an electromagnetic clutch (#3) in order to operate as an additional, independent shutdown system. The main shutdown system consists of 5 safety rods (#5) which are fully withdrawn during normal reactor operation but can be quickly inserted by spring or pneumatic forces if required.

The pumps of the primary cooling circuit are equipped with flywheels. The corresponding two primary pipes (#8) as well as the three pipes of the emergency cooling circuit (#10) are connected with check valves against reverse flow. They all end in a collector (#7) which leads to the header of the core channel tube (#6), both of them being designed in a way that rupture can be excluded. The pressure of the primary circuit at this position is about 9 bar and the flow rate about 320 kg/s. A few hours after shutdown all pumps can be switched off and the core will be cooled by natural convection since the two corresponding flaps (#11) open

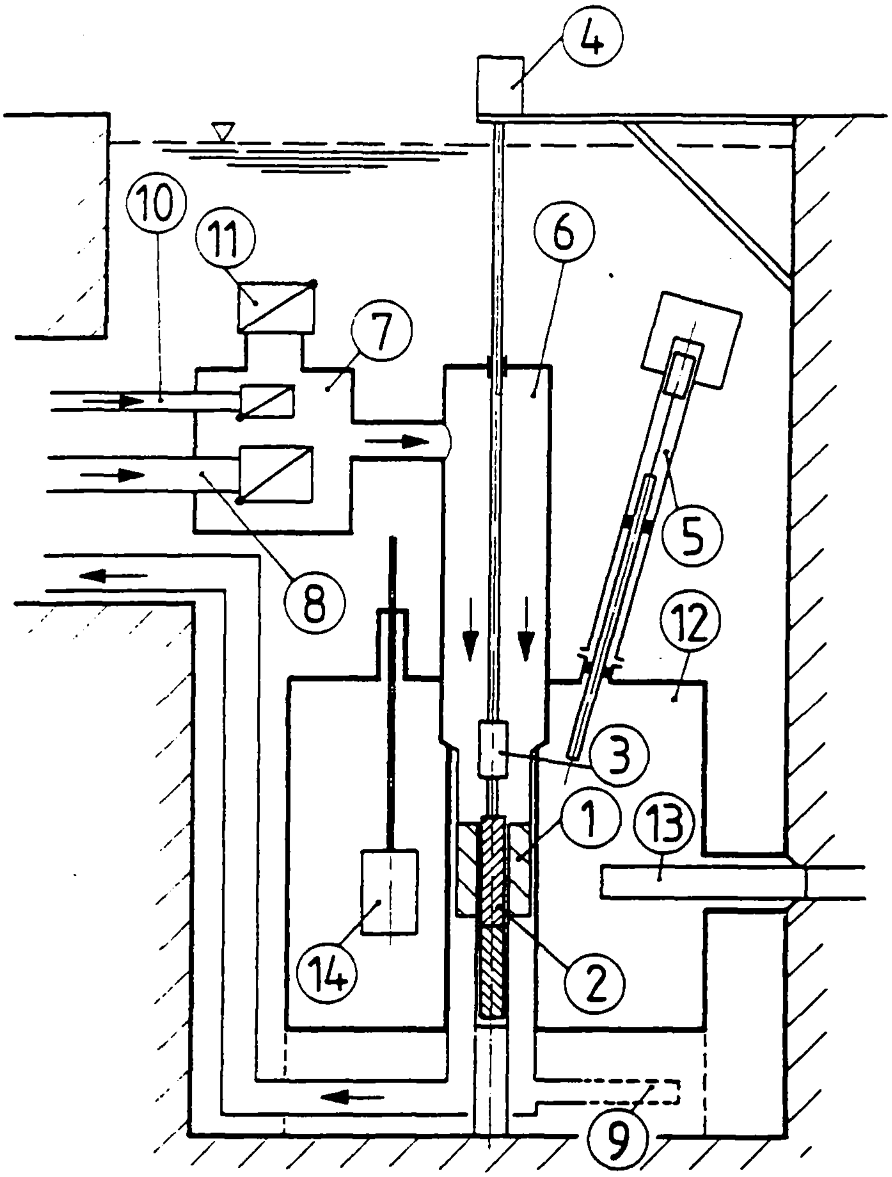

Fig. 1: Schematic vertical cut through the reactor pool of the FRM-II (Interatom GmbH; from /3/). The meaning of the various numbers is as follows:

1 fuel element (compact core)
2 central control rod (with beryllium follower)
3 electromagnetic clutch
4 drive mechanism of control rod
5 shutdown safety rod (5 x)
6 header of the core channel tube
7 collector of the primary pipes
8 primary cooling pipe (2 x)
9 opening sieve to the pool
10 emergency cooling pipe (3 x)
11 flap (valve) for natural convection (2 x)
12 D_2O moderator tank
13 horizontal beam tube (11 x)
14 cold neutron source

automatically and since the primary circuit is always connected with the pool through the sieve #9. - Finally, as an example of the experimental installations one of the 11 horizontal beam tubes (#13) and a vertical cold source (#14) are also shown in Fig. 1 /3,4/.

Some additional features of the present design status of the overall cooling concept become evident from Fig. 2 /3,4/. On the top of the figure the reactor pool with the compact core and the D_2O tank can be recognized on the right hand side, and the storage pool on the left. The pumps and heat exchangers of the primary core cooling circuit A are located in leak-tight chambers. Each of the two redundant primary systems would be sufficient to cool the core at full power. The closed secondary cooling circuit B serves as a further barrier against the release of fission products and allows the connection of the other cooling circuits through the heat exchangers #1 - #4. The ternary circuit C contains a number of air cooling aggregates which represent the nominal heat sink.

The power generated in the D_2O moderator tank is transferred from the D_2O cooling and purification circuit E through heat exchanger #3 into loop B. Similarly, the heat production originating from experimental installations as, e.g., the cold neutron source is discharged through the circuit F and heat exchanger #4. Finally, the pool water cooling and purification circuit G (not fully shown in Fig. 2) is connected with the heat exchangers #1 and #2.

The emergency core cooling system D is independent of the other systems and again consists of primary, secondary and ternary loops. The three battery-driven primary emergency pumps D - each of them being again sufficient to cool the core (after shutdown) - can feed pool water through the core and - by means of the sieve at the lower end of the core channel tube (Fig. 1) - back to the pool. In this way the thermal capacity of the whole reactor and storage pool water can be made use of as a further heat sink. Recooling of the pool water would be necessary only after a few days and can be performed by the secondary circuit D. The core decay heat would finally be transferred to a close-by river using water from existing wells. - The safety concept of the new FRM-II will be explained in more detail in ref. /4/.

A more realistic vertical cut through the reactor and storage pools has been published in ref. /5/. The reactor building of the

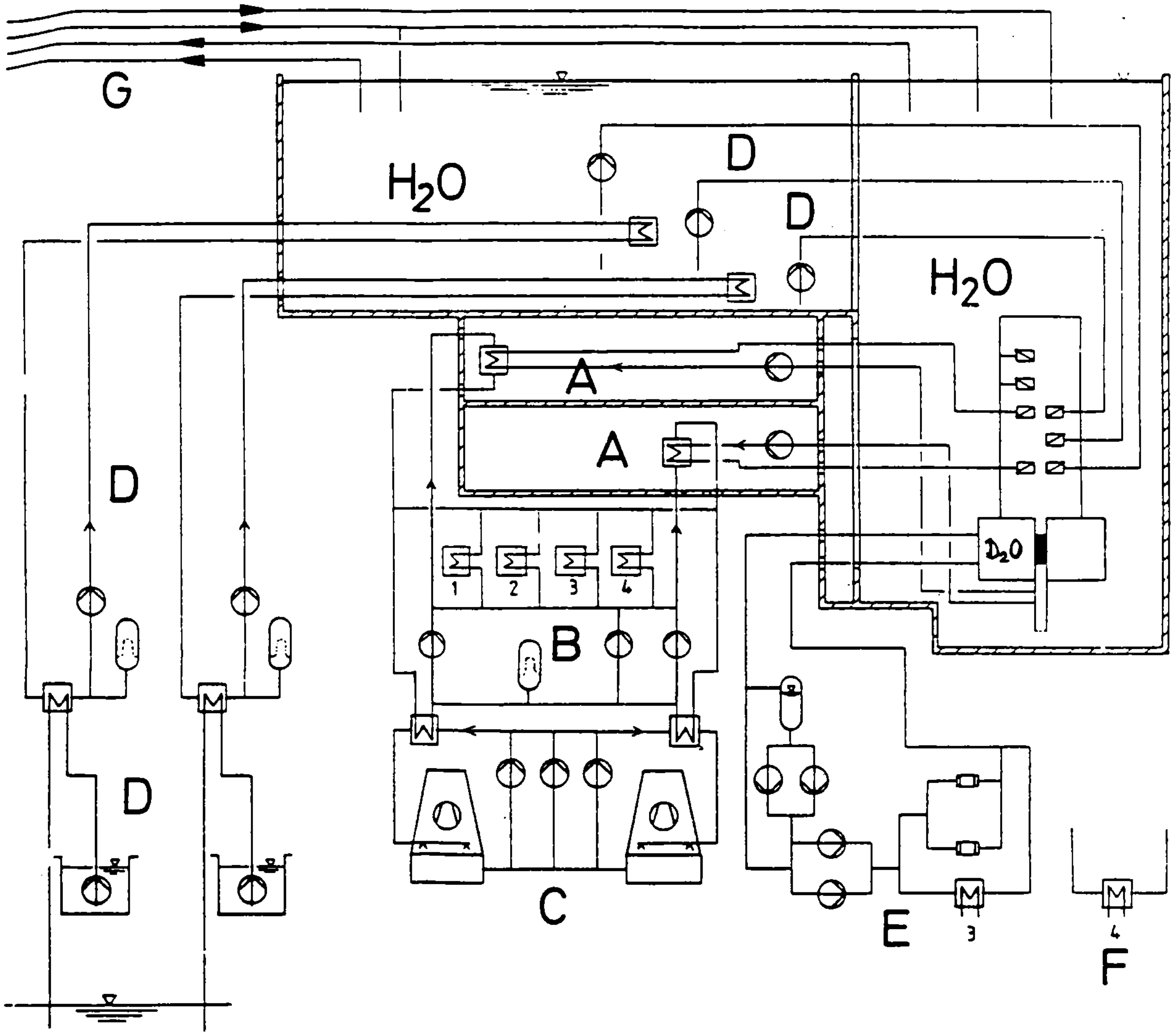

Fig. 2: Scheme of the preliminary cooling concept of the FRM-II (Interatom GmbH).

A	primary core cooling circuit
B	secondary circuit
C	ternary circuit with air cooling aggregates
D	emergency core cooling circuit
E	D_2O moderator cooling circuit
F	experimental installations cooling circuit
G	pool water cooling and purification circuit
1-4	further heat exchangers

new FRM-II will have a quadratic cross section of about 40 m side length on the ground floor level where nearly the full area can be used for the beam tube experiments. This "experimental hall" will be completely separated from the "reactor hall" which extends above the pool water level and where fuel handling and irradiation experiments can be performed. On this level the cross section of the building will be an octogon. A vertical cut through the reactor building has also been presented in ref. /5/.

Finally, a view of the whole research reactor facility, according to the present design status, is shown in Fig. 3. The new FRM-II reactor building is to be seen on the left. It is connected with a low "neutron guide hall" where beam tube experiments with cold neutrons can be performed. This experimental area even extends into the egg-shaped building of the existing reactor FRM. This old FRM has been the first nuclear reactor in Germany and will be shut down and decommissioned shortly before the new FRM-II goes into operation.

ACKNOWLEDGEMENTS

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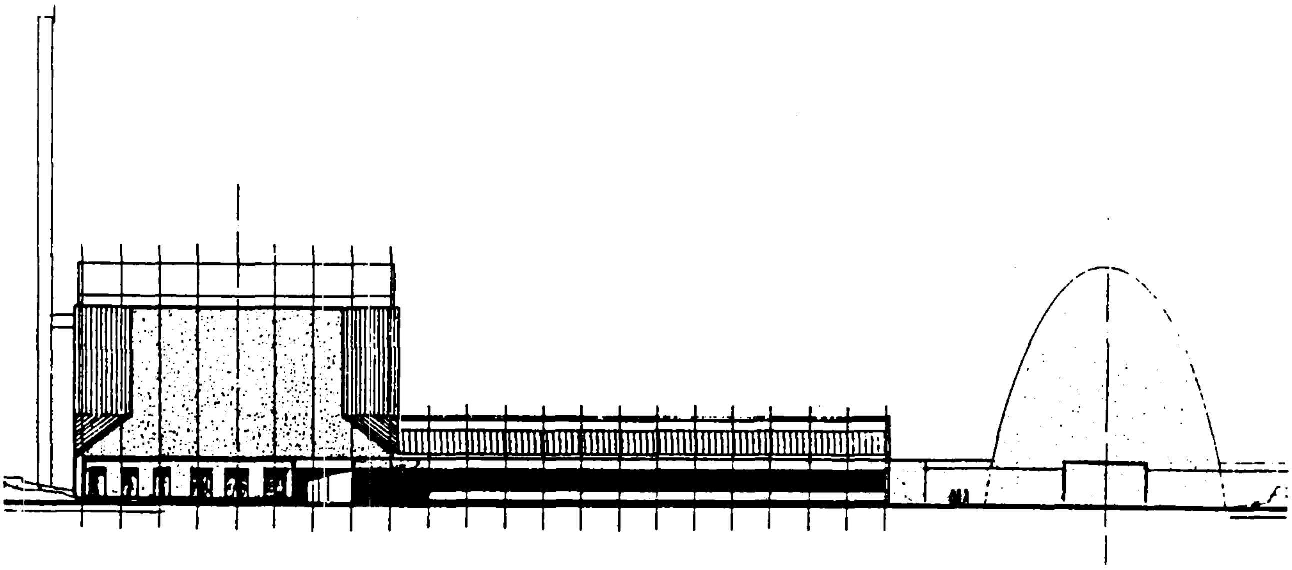

Fig. 3: View of the new research reactor facility according to the present (preliminary) design status. The building of the new FRM-II on the left will be constructed in about 100 m axial distance from the egg-shaped building of the existing FRM, with the new neutron guide hall in between. The architectural design is from Prof. Angerer, TUM.