The Advanced Pressurized Water Reactor (APWR)
- A Complementary System to the Closed Fuel Cycle -

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For some years several APWR concepts have been investigated with the intention of finding out the extent to which the conversion properties of a light water reactor (LWR) core can be improved [1, 2, 3].
In comparison to present thermal water reactors such a high converter reactor, as an element of the closed U-Pu fuel cycle, includes the potential to enhance uranium utilization by a factor of about four [4]. The considerations are based on the idea to keep as much as possible to the commercially proven and widely standardized PWR plant and to its component technology, including the reactor pressure vessel, so that modification are essentially restricted to the reactor core and the control rod system. In the following paragraphs two different APWR concepts will be presented which were developed recently by cooperating groups of KfK and Kraftwerk Union (KWU).

In both concepts the increase of the conversion ratio from o.6 (PWR) up to o.9 to o.95 (APWR) is achieved by spectrum hardening via significant reduction of the moderator-to-fuel-volume ratio. For this reason, the typical square rod lattice of a PWR fuel element has been modified into a tight triangle arrangement structure which results in a hexagonal cross-section of an APWR fuel element. Fig. 1 illustrates the main APWR design characteristics in comparison with a 13oo MW_e PWR core.

Regarding the compact fuel assembly design two concepts have been developed:

- the <u>homogeneous</u> version is composed of uniform fuel rods containing MOX fuel with a fissile enrichment of 7.5 to 8 % Pu. Characteristic for the rod bundle is its pitch to diameter ratio p/d = 1.12;
- the <u>heterogeneous</u> version is composed of two zones accommodating different fuel pin types. The highly enriched ($\approx$15 % Pu_{fiss}, p/d = 1.24) central seed zone is designed above all under power generating aspects whilst the function of the surrounding hexagonal blanket ($\approx$ 5 % Pu_{fiss}, p/d = 1.o6) is determined rather by conversion aspects.

Comprehensive investigations related to the neutron physics and thermohydraulics of both APWR core types were performed [5,6] and complemented by first safety analysis studies [7]. The results have served for a general comparison of the APWR system with a 13oo MW_e PWR plant, on the one hand, and for an intercomparison of the individual concepts, on the other hand. In this frame the following items have been discussed:

- global plant (modifications against standard PWR unit),
- core (fuel rod assembly, fissile inventory, conversion ratio, burnup),
- operating behavior (DNB ratio, Doppler coefficient),
- accident behavior (void coefficient, ATWS, LOCA),
- licensability (German RSK guidelines),
- economic and strategic perspectives.

The result of this assessment can be summarized as follows: According to the present state of knowledge the alternative APWR concepts described above are both interesting and feasible from the technical point of view.

Concerning individual advantages, the homogeneous core variant turned out to be more attractive under design and fabrication aspects. With respect to the overall core power which can be generated within an unchanged PWR reactor pressure vessel geometry this variant seems to be more favorable. On the other hand, the heterogeneous version reveals some more advantageous neutronic properties, in particular with respect to the conversion potential and the void reactivity behavior.

In this context it should be mentioned that both concepts have been developed partly on rather conservative assumptions. This comprises thermohydraulic design parameters as well as reactivity calculation methods. Therefore, R+D work in the near future will follow two lines, the main emphases being laid on

- the experimental verification of theoretical models currently applied to tight lattice core studies and, in parallel,
- the best estimate optimization of the individual core designs.

At the end of this intermediate period one reference concept will be defined for more detailed feasibility investigations.

From the economic and strategie points of view APWRs are to be considered in relation with fast breeder reactors (FBRs) rather than with LWRs [8]. As long as prices for natural uranium and separation work will be kept at the present low level LWRs will continue to be ahead commercially. The advantage of advanced systems, their better utilization of resources, will not be of interest until the possibility of shortage in uranium supply will be taken into account for any reasons whatsoever. To the same extent as the electricity generating costs of the individual systems converge, an LWR-APWR-FBR symbiosis will become interesting and provide a flexibility in terms of supply strategy which will allow to adjust the fuel cycle to future market trends and boundary conditions in an optimum way.

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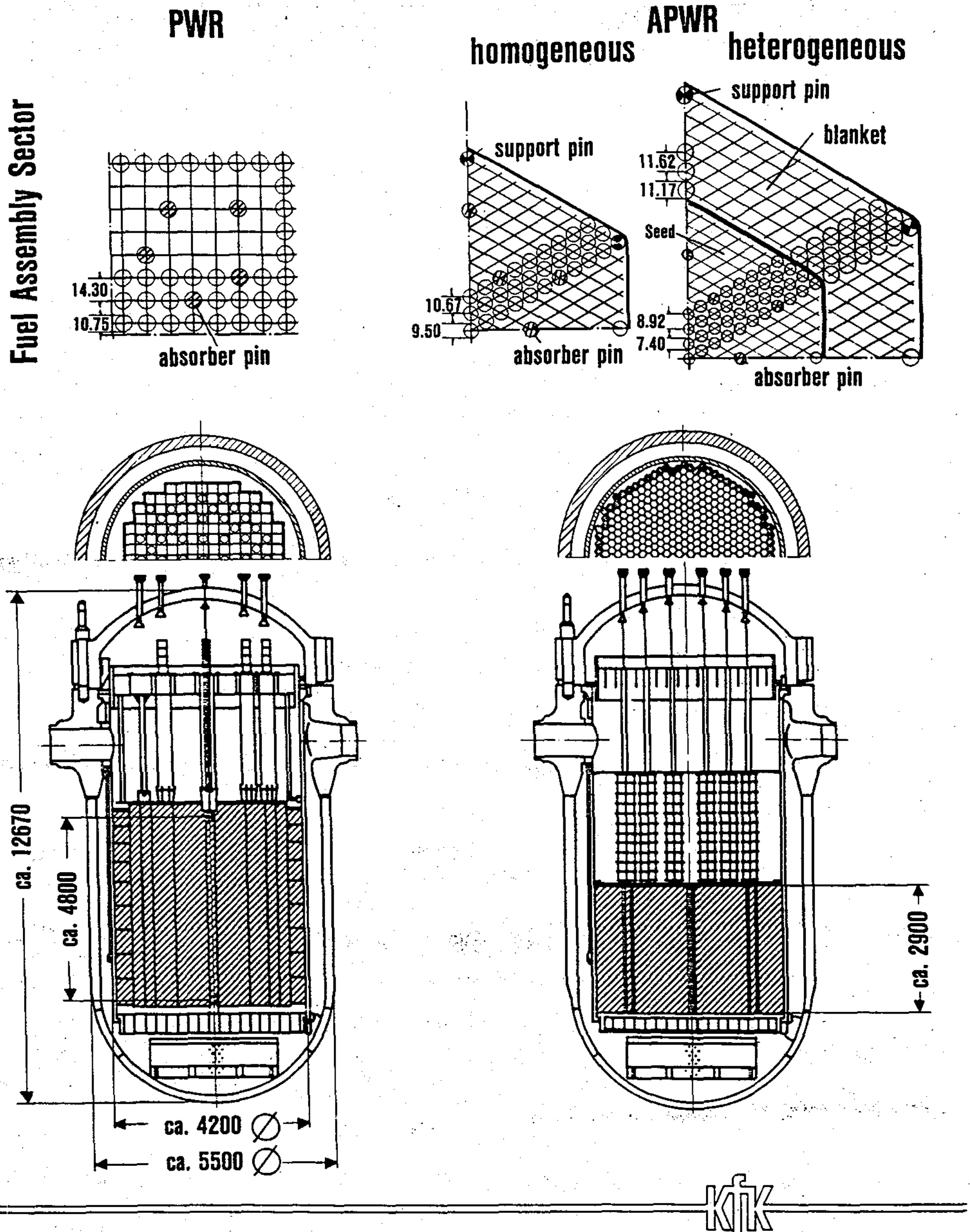

FIG. 1 APWR CORE DESIGN CHARACTERISTICS

IN COMPARISON WITH A 13oo MW_e PWR CORE

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