SOME ASPECTS OF AN ADVANCED STELLARATOR REACTOR

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Abstract: The W VII-AS configuration /1/ is scaled up to reactor dimensions. Available space for a blanket, forces and stresses in the twisted coils are discussed leading to the result that a W VII-AS reactor coil set seems to be feasible. Ignition conditions are studied using a neoclassical transport model. Stable burning points are found with temperatures below 10 keV.

I. Introduction: The basic properties of the W VII-AS configuration /1/ are the reduced neoclassical transport losses, reduced secondary currents as compared with classical stellarators and a modular coil set consisting of 45 twisted coils. This paper concentrates on the problem whether this coil set is feasible under reactor conditions, whether there is enough space for a blanket and discusses the ignition conditions. Questions of MHD-stability and ß-limits are not discussed in this paper.

II.Configuration: Scaling up the W VII-AS configuration to reactor dimensions under the condition of leaving 1.8 m space for a blanket yields a device of 25.5 m major radius and 1.65 m minor plasma radius.

Table I: Average system parameters

	W VII-AS	Ref./2/	AS-reactor
Major radius /m/	2.06	20.6	25.5
Plasma radius /m/	0.2	1.30	1.65
Magnetic field /T/	3.5	5.3	5.3
Rotational transform	0.4	0.48	0.58
Aspect ratio	10	16	16
Coil aspect ratio	4.3	4.3	4.9
Coil current density /MA/m^2	27	13.3	9.8
Maximum field on the coils /T/		9-10	8-9

The coil set of the AS-reactor consists of 50 coils arranged in 5 periods. In reactor dimensions no special coils for neutral beam injection are necessary. One period of the coil set is shown in fig. 1, the contours visualize the current carrying volume. The coils have elliptic poloidal cross sections, see fig.2. There the vacuum magnetic surfaces are also shown for different toroidal angles. The minimum distance between coils and the last magnetic surface is 1.8 m. Thus sufficient space for blanket and shield is provided. The maximum magnetic field on the coils is 8-9 T, depending on the specific coil.

Forces and stresses of this coil set have been calculated using a simple support sheme /2/. Replacing the inner support ring, as described in ref./3/, by an outer ring and employing elastic paddings between the coil and its lateral structure reduces the peak value of the von-Mises stress of the coil compound to an uncritical value of about 70 MPa. Less than 10 coils per period would give better access for maintainance but also would increase the magnetic field ripple and the ratio B_{max}/B_o (B_o = magnetic field in the plasma).

III. Ignition conditions: A simple transport code is used to calculate temperature and density profiles with α-particle heating as a heating mechanism and neoclassical transport as loss mechanism. In electron heat conduction and particle transport the $1/\nu$ scaling due to trapped particles is taken into account whereas ion heat conduction follows the plateau scaling. This choice is justified in /4 /. The refuelling mechanism is modelled by a given particle deposition profile. Particle influx and deposition profile are the external parameters in order to control the burning plasma.

It is found that neoclassical transport is compatible with an ignited plasma with an average temperature of 6 keV. Increasing the particle input flux ϕ_o leads to higher densities, higher temperatures and higher fusion power output. Fig. 3 summarizes the plasma parameters as a function of the input flux ϕ_o. In this figure particle refuelling peaks in the center of the plasma (λ =0). With refuelling in the outer regions ignition is only possible above $T \approx 8$keV. Fig. (4) shows plasma parameters under this condition: thermal fusion power is 3.6 GW, $\bar{\beta}$=5.3 %, T_e =12 keV, T_i = 10 keV which is the range of optimum burn temperature. The thermal stability of the ignited plasma is provided by the temperature dependence of the trapped electron losses. If the ion thermal conductivity also follows the $1/\nu$-scaling, ignition is still possible but the required ß-values are above 10 %. These values are above the equilibrium limit of the AS-reactor.

IV. Discussion: Scaling up the W VII-AS configuration to reactor dimensions under the condition of leaving 1.8 m space for a blanket yields a device of 25 m major radius and 1.65 m averaged plasma radius. The maxiumum magnetic field at the coils is 8-9 T. Stress analysis and a proper choice of the support structure demonstrate that a coil set of the AS-type show gross feasibility, for details further engineering studies are required. Ignition in an AS-reactor is possible if the ion thermal losses follow the neoclassical plateau scaling. Stronger trapped ion losses are not tolerable. These calculations do not take into account selfconsistent radial electrical fields. It has to be expected that a radial electrical field contributes to a better confinement of the trapped particles and thus reduces the ion thermal conductivity. The ß-values are only determined by plasma transport, MHD-stability is not considered in this paper. Neoclassical transport allows an ignited plasma at $\bar{\beta}$ = 1.5 %, which could be a stable equilibrium. But the fusion power in this case is too low for a reasonable reactor.The present analysis indicates that the key problems to be addressed of a modular AS-reactor are ß-limits and neoclassical transport rather than the technical feasibility of the modular coil set.

References

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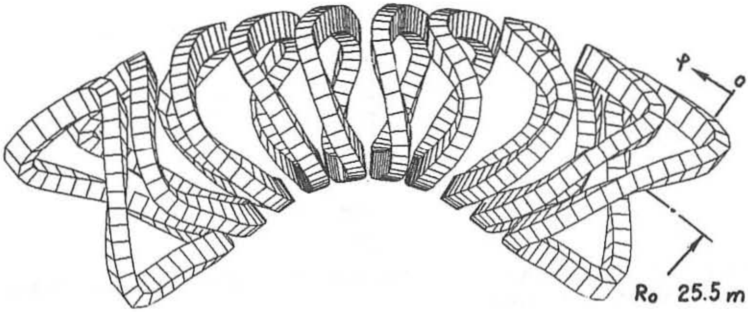

Fig.1 Modular coil arrangement of the AS-reactor, one field period.

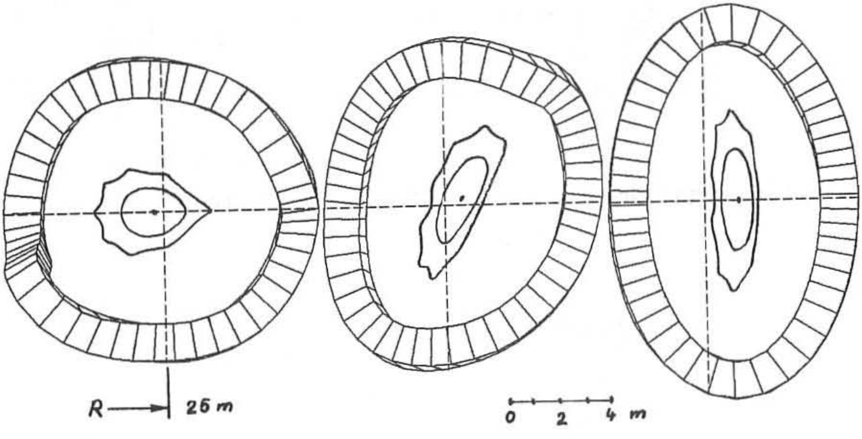

Fig.2 Cross section of magnetic surfaces with adjacent twisted coil, at 0, 1/4, 1/2 field period.

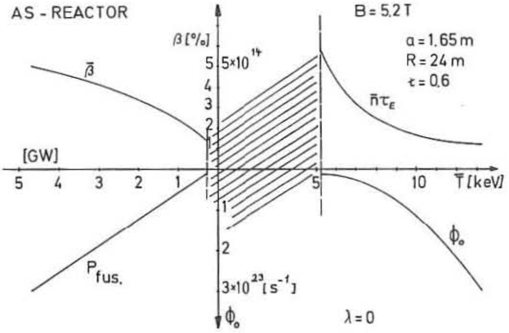

Fig.3 Plasma parameters as a function of refuelling rate ϕ_o. Refuelling in the center. ($\lambda = 0$)

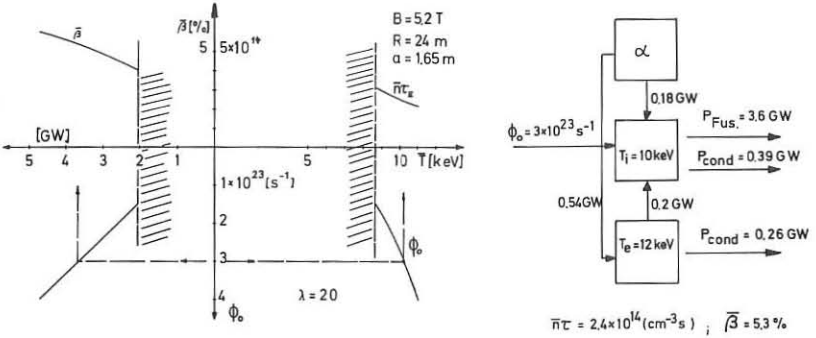

Fig.4 Plasma paramters with refuelling in the boundary region. ($\lambda = 20$)

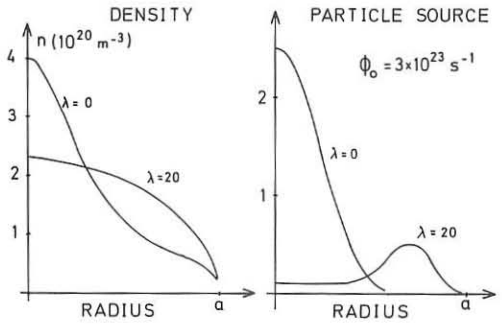

Fig.5 Density profiles and particle deposition profiles. Comparison of central refuelling with boundary refuelling.