§1. Modification of Design Parameters on LHD-type Reactor FFHR2

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In order to make clear the key R&D issues for D-T fusion power plants on the basis of major advantages such as current-less plasma and intrinsic diverter configuration in helical system, with including common engineering issues in other plasma confinement concepts, the conceptual design studies on LHD-type helical reactors have been curried out by introducing physics and engineering results obtained in the LHD project, with collaboration works in wide research areas on fusion science and engineering in the universities of Japan.

In the LHD-type reactor design the coil pitch parameter γ of continuous helical winding has been adjusted beneficially to reduce the magnetic hoop force (Force Free Helical Reactor: FFHR) while expanding the blanket space, and a self-cooled liquid blanket using molten salt Flibe (BeF_2-LiF) has been proposed, due to its advantages of low MHD pressure loss, low reactivity with air, low pressure operation, and low tritium solubility. Standing on these advanced concepts, the design study on FFHR has been curried out from 1991 under construction and operation of LHD.

In the direction of decreasing reactor size, many issues still remain, such as insufficient tritium breeding ratio (TBR) and nuclear shielding for superconducting (SC) magnets, and replacement of blanket due to high neutron wall loading and narrowed maintenance ports due to the support structure for high field coils.

Therefore, the design parameters of FFHR2 are modified to those of FFHR2m, as shown in Table 1. The coil pitch parameter γ is 1.15 in FFHR2m1 to expand the blanket space and to reduce electromagnetic force, while γ is 1.25 in FFHR2m2 with inner shift of the plasma center as same as the standard condition in the present LHD. In both cases the major radius R is increased and the toroidal field B_0 is decreased within B_{max} of 13T. Then the blanket space is as wide as 1.2m, resulting in sufficient TBR and nuclear shielding for SC magnets. At the same time the wide maintenance ports are possible due to simplification of coil-supporting structures(Fig.2).

The self-ignition analyses have revealed the enhancement factor can be reduced below 2 of ISS95 confinement scaling with introducing the recent LHD results on the density of 1.5 higher than the Sudo limit (Fig. 1). The next design issues are on start-up heating, fueling, diverter pumping, and so on.

Reference:
A. Sagara et al., Nuclear Fusion 45 (2005) 258-263.

Table 1. Design parameters of helical reactor FFHR

Design parameters			LHD	FFHR2	FFHR2m1	FFHR2m2
Polarity	l		2	2	2	2
Field periods	m		10	10	10	10
Coil pitch parameter	γ		1.25	1.15	1.15	1.25
Coil major Radius	Rc	m	3.9	10	14.0	17.3
Coil minor radius	ac	m	0.98	2.3	3.22	4.33
Plasma major radius	Rp	m	3.75	10	14.0	16.0
Plasma radius	ap	m	0.61	1.2	1.73	2.80
Blanket space	Δ	m	0.12	0.7	1.2	1.1
Magnetic field	B0	T	4	10	6.18	4.43
Max. field on coils	Bmax	T	9.2	15	13.3	13.0
Coil current density	j	MA/m2	53	25	26.6	32.8
Weight of support		ton	400	2880	3020	3210
Magnetic energy		GJ	1.64	147	120	142
Fusion power	P_F	GW		1	1.9	3
Neutron wall load		MW/m2		1.5	1.5	1.3
External heating power	Pext	MW		70	80	100
α heating efficiency	ηα			0.7	0.9	0.9
Density lim.improvement				1	1.5	1.5
H factor of ISS95				2.40	1.92	1.76
Effective ion charge	Zeff			1.40	1.34	1.35
Electron density	ne(0)	10^19 m-3		27.4	26.7	19.0
Temperature	Ti(0)	keV		21	15.8	16.1
Plasma beta	<β>	%		1.6	3.0	4.1

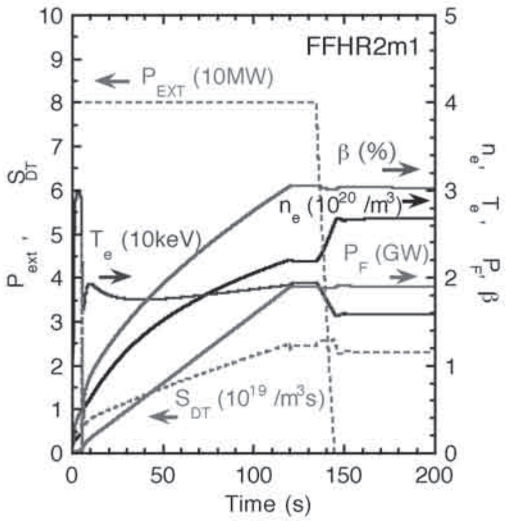

Fig.1. Self-ignition access calculation in FFHR2m1.

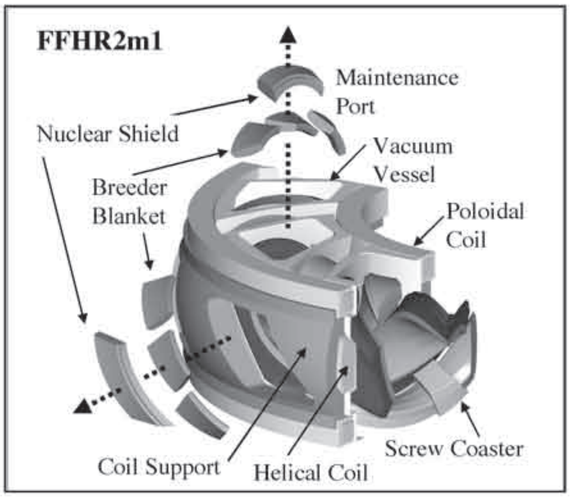

Fig.2 3D illustration of wide maintenance ports