

Recent Design and Development in LHD-type Reactor Studies

Akio Sagara

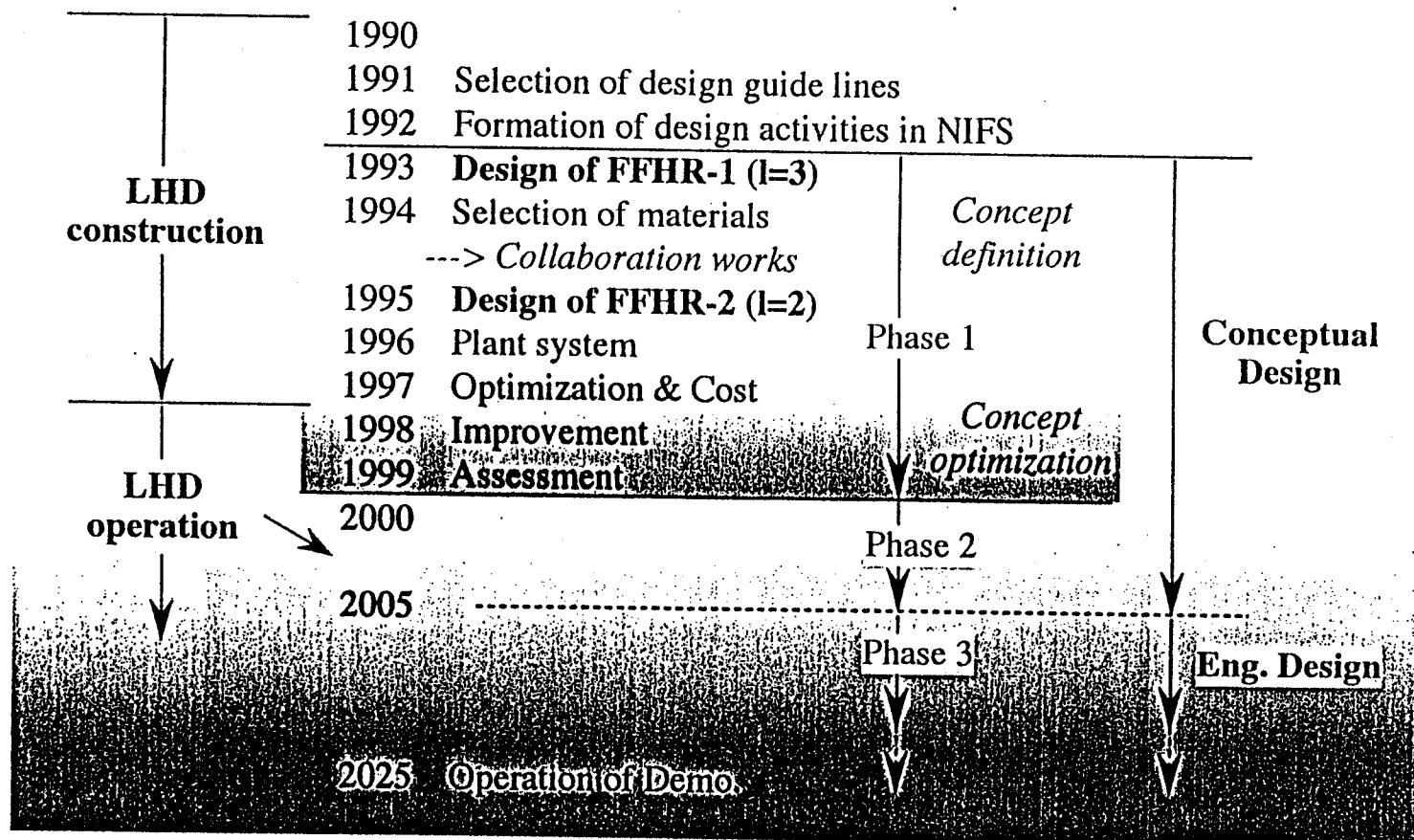
National Institute for Fusion Science

Presentation outline

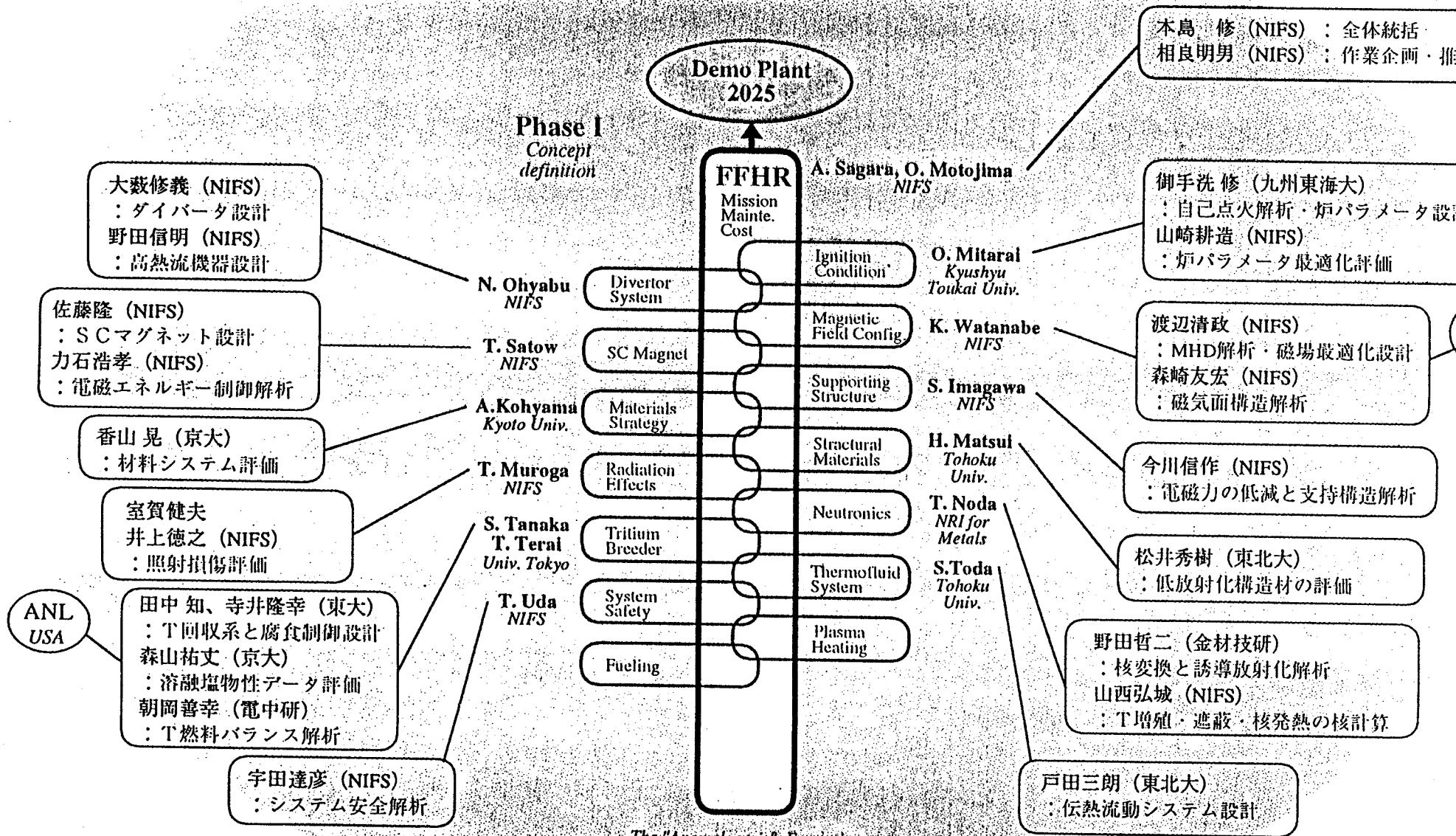
- Compact design FFHR-2**
- 3D Nuclear blanket design**
- R&D works on Flibe**

*US-J Workshop on APEX-6/FHPD
Feb. 16-19, 1999, UCLA*

Based on physics and engineering results in the LHD project, D-T demo-reactors have been studied



Collaboration & Publication Network



FFHR has many inherent and passive safety features

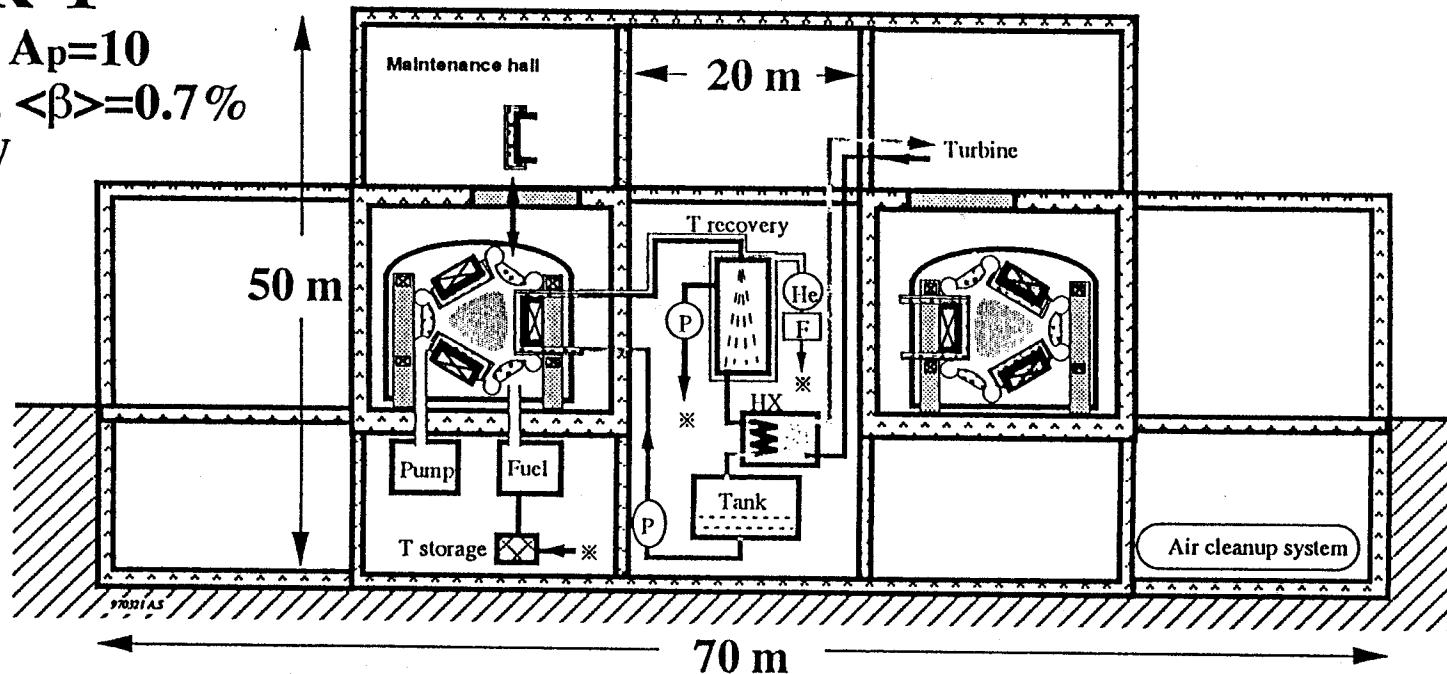
- current-less plasma,
- steady state operation,
- use of Flibe,
- high-temp. &T devices inside the torus area.

FFHR-1

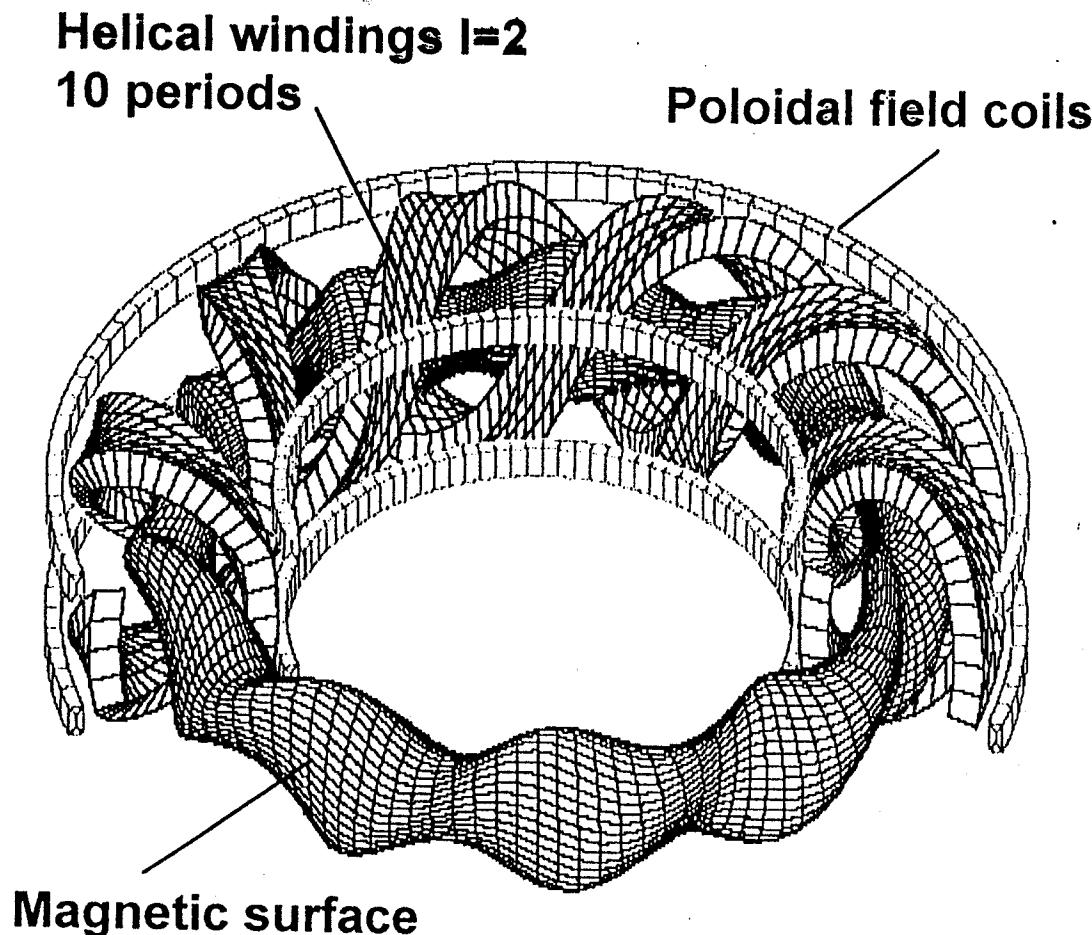
$R=20\text{m}$, $A_p=10$
 $B_0=12\text{T}$, $\langle\beta\rangle=0.7\%$
 $P_f=3\text{GW}$

$\ell=3$
 $m=18$
 $\gamma=1$

Flibe
-JLF-1

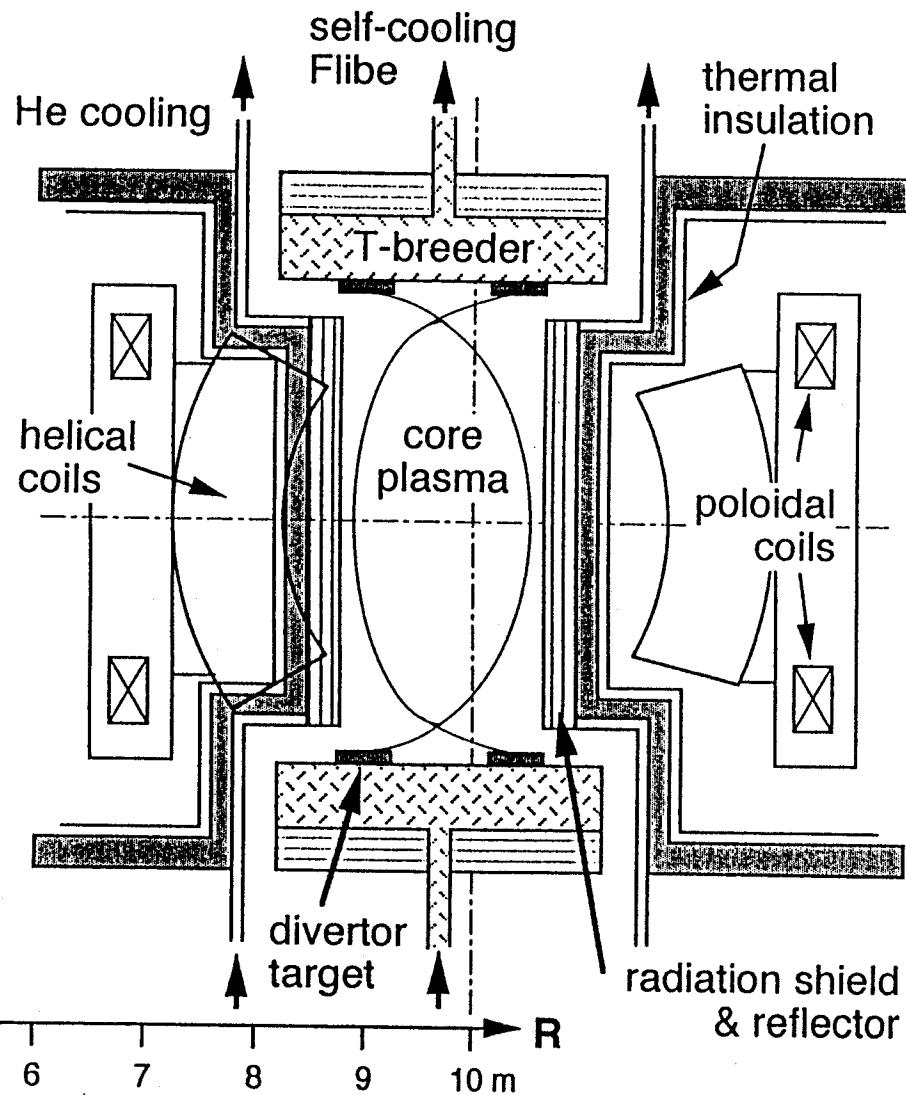


FFHR-2



Major radius	10 m
Av. coil radius	2.3 m
Av. Plasma radius	1.2 m
Magnetic field	10 T
Max. field	13 T
$I = 2$	
Number of periods	10
Pitch parameter γ	1.15
Modulation α	+0.1
Current MA/coil	50
Stored energy GJ	147

FFHR-2



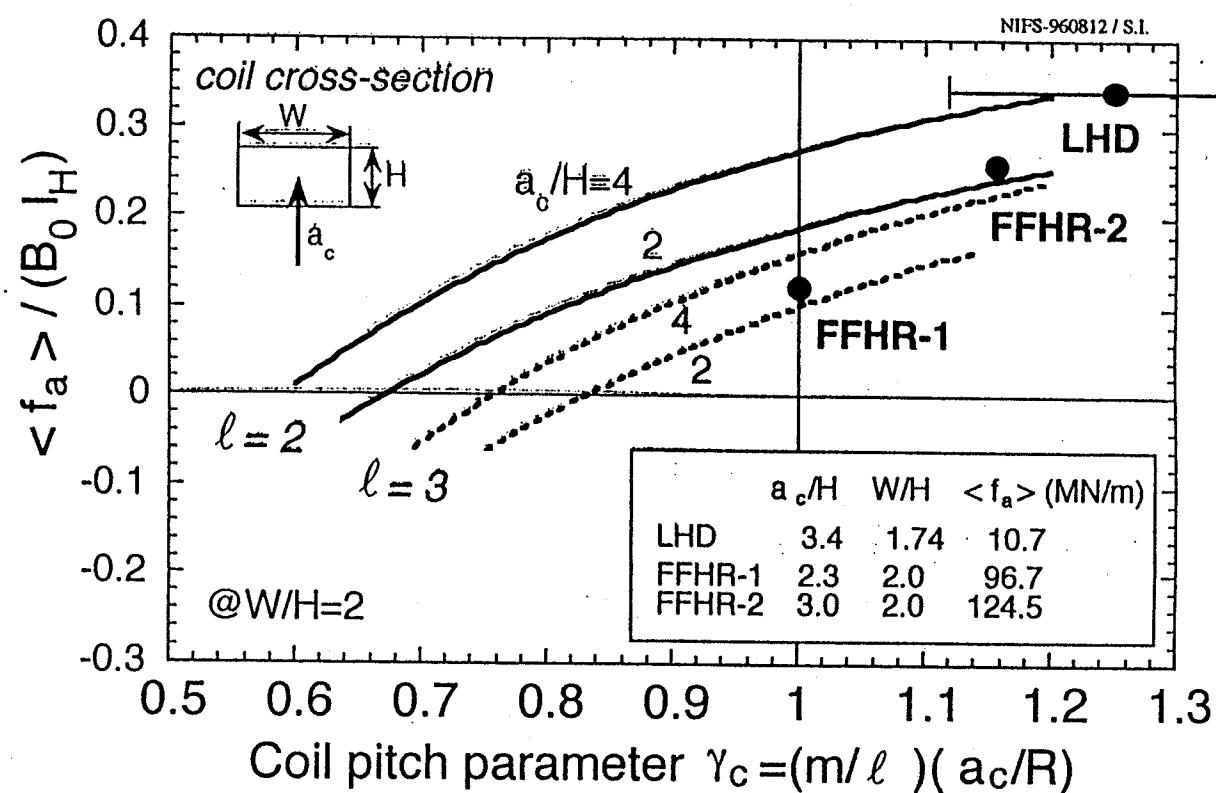
Parameters	LHD	FFHR-1	FFHR-2
major radius : R	3.9	20	10 m
av. plasma radius : $\langle a_p \rangle$	< 0.65	2	1.2 m
fusion power : P_f (GW)	-	3	1 GW
external heating power : P_{ex}	< 20	100	100 MW
neutron wall loading : P_n	-	1.5	1.5 MW/m ²
toroidal field on axis : B_0	4	12	10 T
average beta : $\langle \beta \rangle$	> 5	0.7	1.8 %
enhancement factor of τ_{LHD}		1.5	2.5
plasma density : $n_e(0)$	1.E2	2.E20	2.8E20 m ⁻³
plasma temperature : $T_e(0)$	> 10	22	27 keV
effective ion charge : Z_{eff}		1.5	1.5
alpha heating efficiency : η_α	-	0.7	0.7
alpha density fraction : f_α	-	0.05	0.05
synchrotron reflectivity : R_{eff}	-	0.9	0.9
hole fraction : f_h	-	0.1	0.1
av. heat load on divertor	< 10	1.6	1.5 MW/m ²
number of pole : ℓ	2	3	2
toroidal pitch number : m	10	18	10
pitch parameter : γ	1.12 < 1.25 < 1.37	1	1.15
coil modulation : α	+ 0.1	0	+ 0.1
av. helical coil radius : $\langle a_c \rangle$	0.975	3.33	2.30 m
coil to plasma clearance : δL	0.03	1.1	0.70 ~ 1.25 m
coil current : I_H	7.8	66.6	50 MA/coil
coil current density : J	(53)	27	25 A/mm ²
max. field on coils : B_{max}	(9.2)	16	13 T
stored magnetic energy	1.64	1290	147 GJ
construction cost		50 Byen	

Force-free-like Continuous Coils

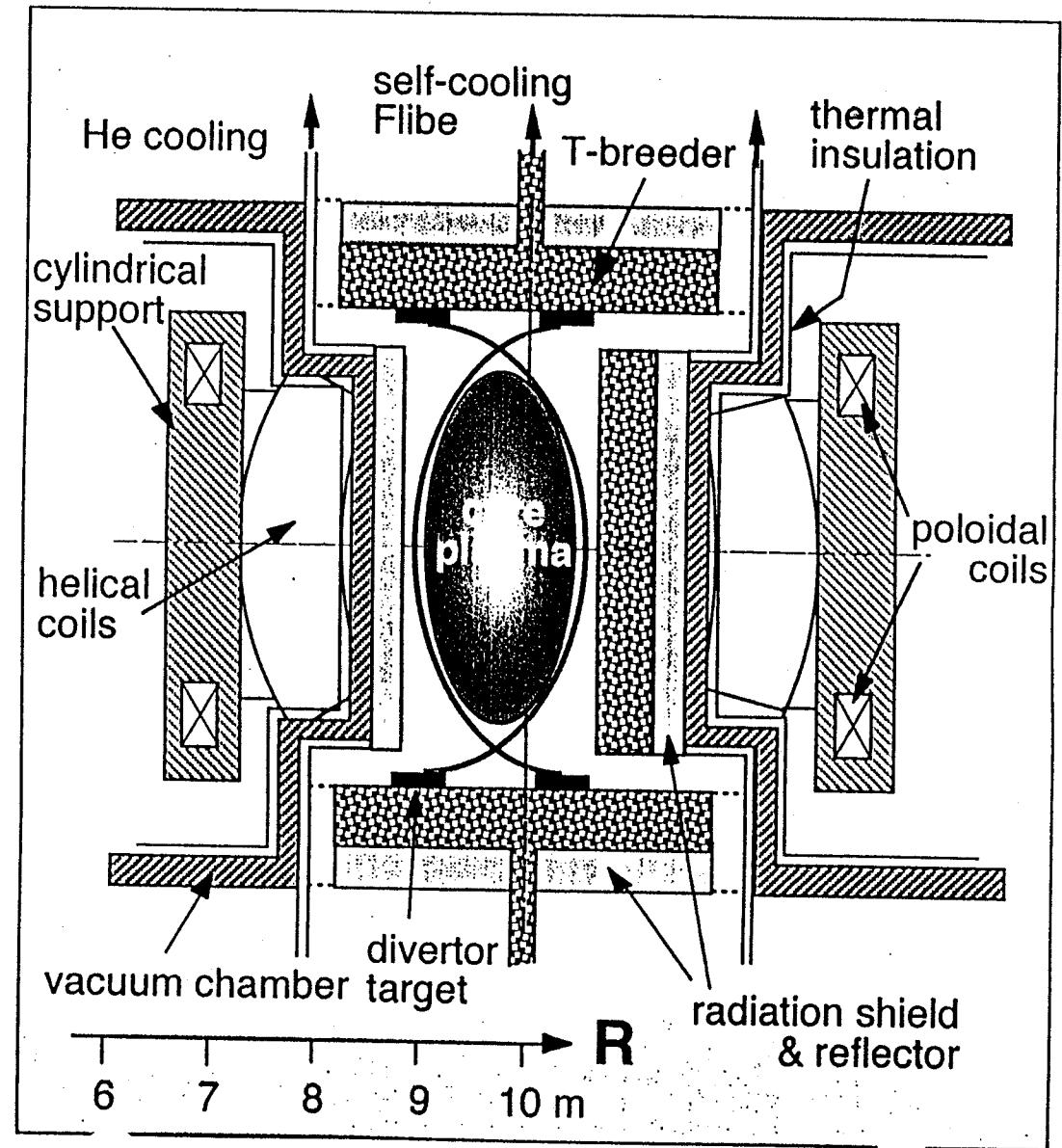
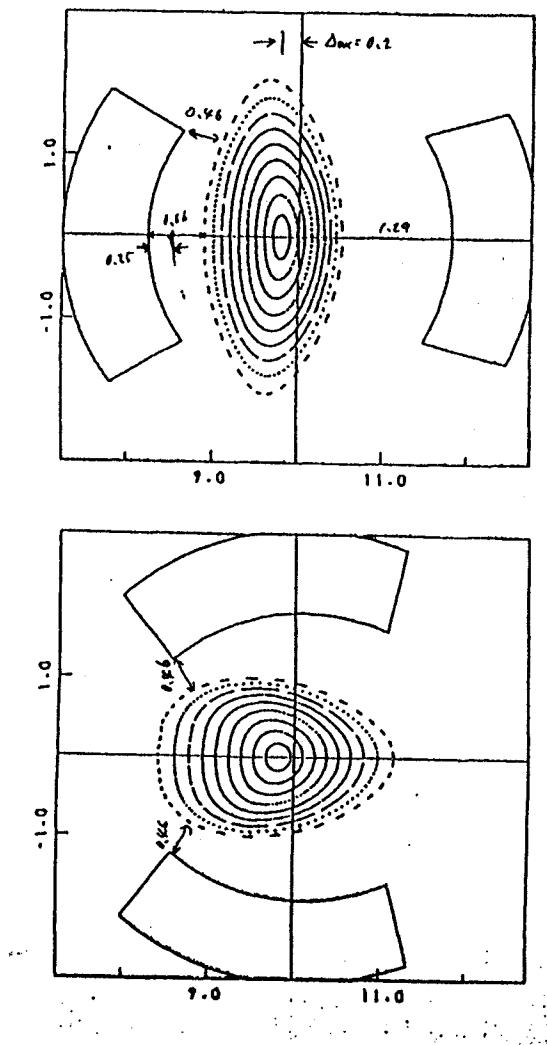
, with the helical pitch $\gamma = 1.15$ which is within
the experimental range in LHD,

simplifies the
coil supporting
structure

with a high
magnetic field
and low
plasma beta.

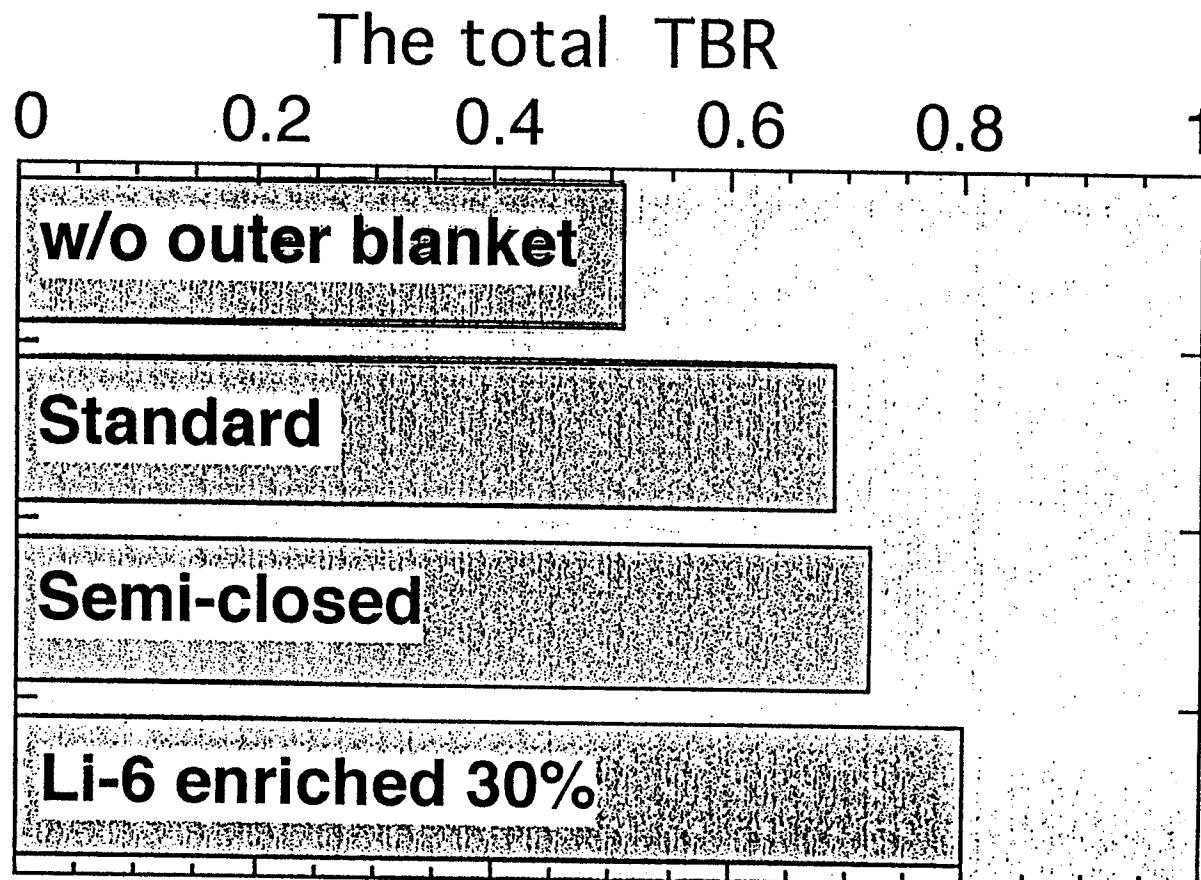


Localized Blanket Concept



Under optimization using the 3-D Monte Carlo code MCNP-4B

to obtain the total tritium breeding ratio TBR >1.1 as well as nuclear shielding



Selection of molten-salt Flibe as a self-cooling T breeder

from the main reason of safety

owing to
low T solubility

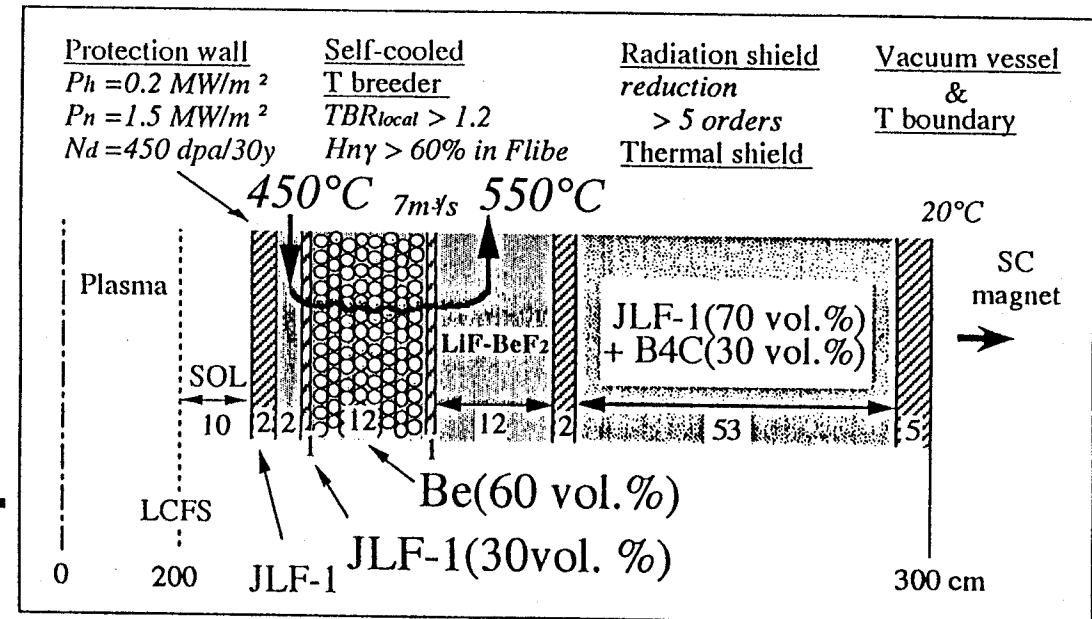
(~8 order lower than liq.Li)

low reactivity

low pressure ope.

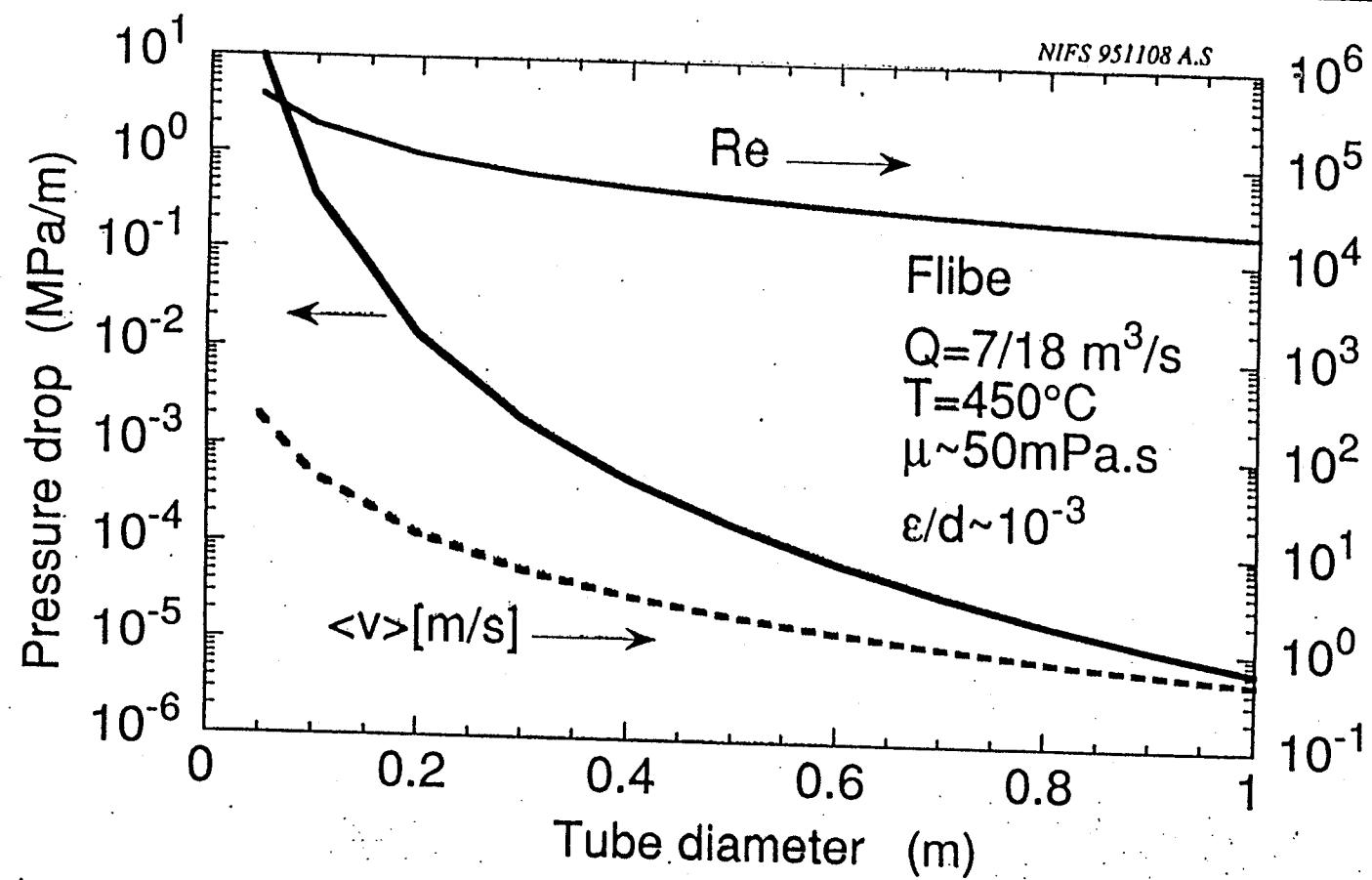
(< 1MPa)

low MHD resist. ($\sim 1\Omega m$)



compatible with a high magnetic field

Possibly below 1 MPa per channel.
The mechanical stress can be kept low.



Low activation ferritic steel JLF-1 (Fe-9Cr-2W) is the first candidate

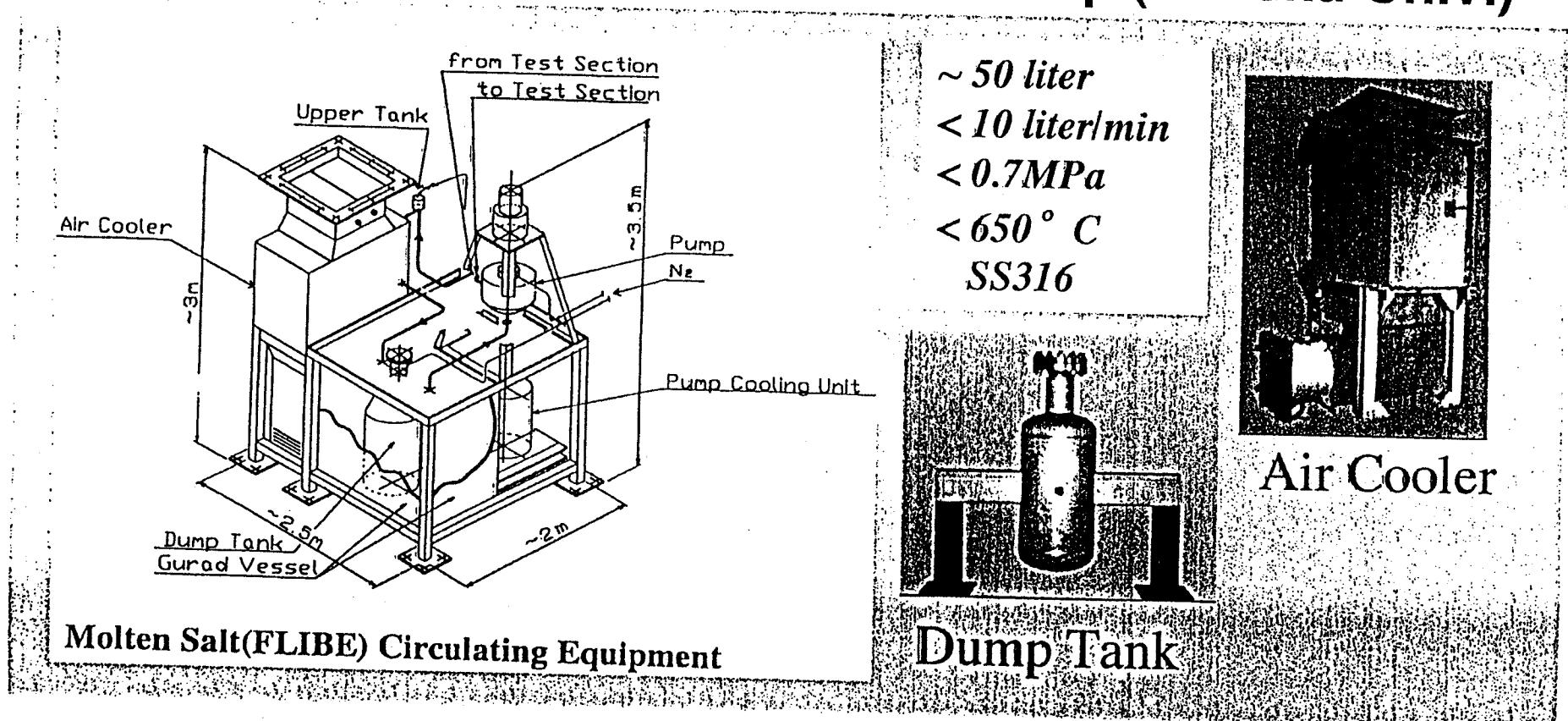
for blanket structural materials

For higher temperature operation over 550°C V-alloy (V-4Cr-4Ti) is an alternative candidate because of its low induced activation, high heat flux capability and low irradiation induced swelling.

However, the compatibility with Flibe is not well known and needs to be studied.

Collaboration works on Flibe R&D are in progress

- ★ in material dipping-tests & n-irrad. (Univ. of Tokyo)
- ★ in constructing an active flow loop (Tohoku Univ.)



In-Situ Tritium Release Behavior From Molten Li₂BeF₄ Salt

ISFNT-4 / A.Suzuki, T.Terai, S.Tanaka / Univ. of Tokyo

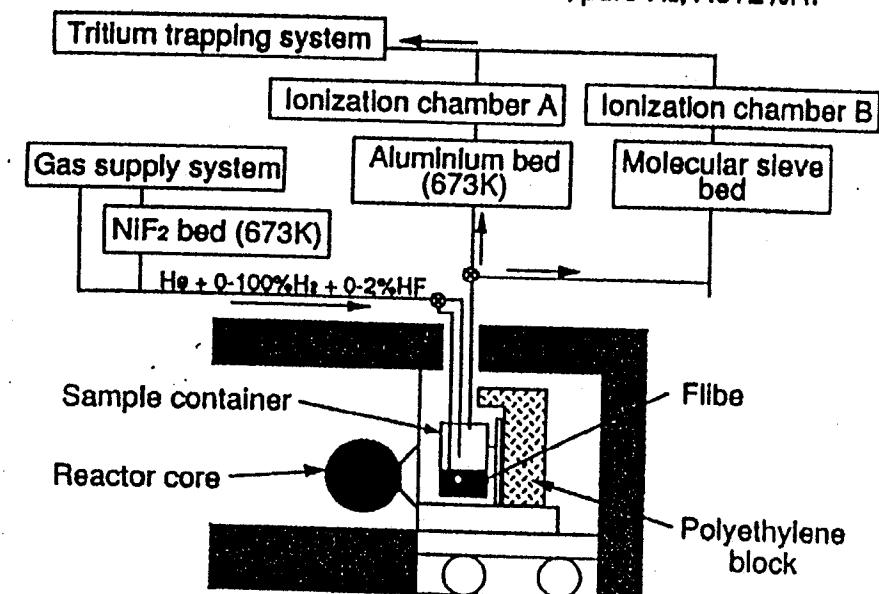
Apparatus for In-Pile Tritium Release Experiment

Fast neutron source : $10^8\text{--}10^9\text{n/cm}^2\text{s}$

("YAYOI" of the University of Tokyo)

Tritium generation rate : $\sim 5\text{Bq/g-Li,s}$

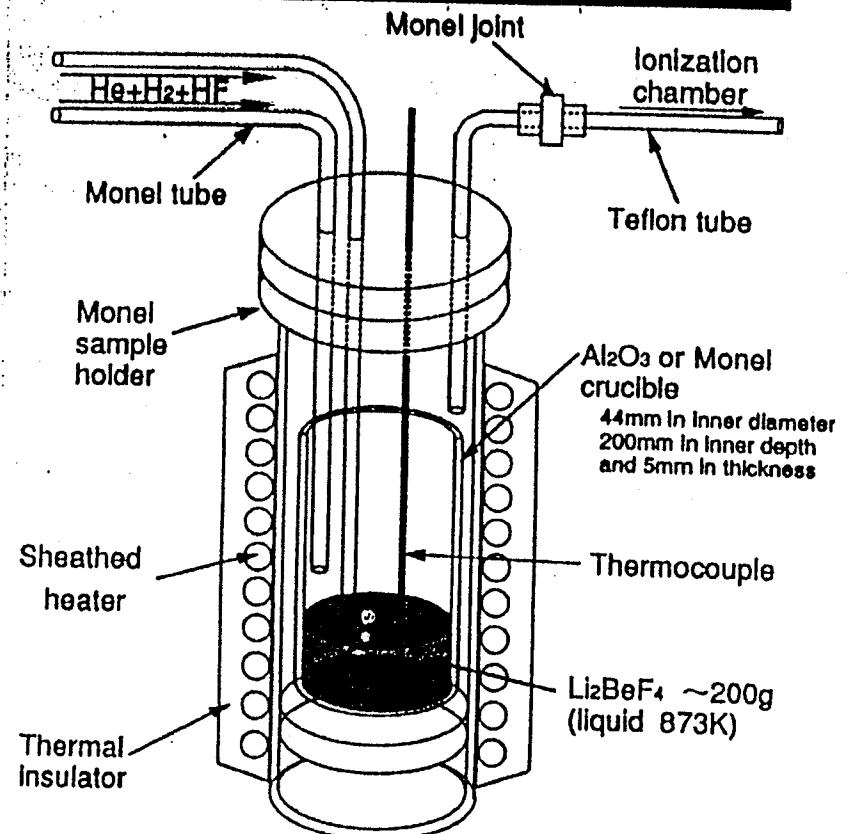
Purge gas : pure He, He + 0.001-10%H₂, pure H₂, He+2%HF



TF is converted to HT in the aluminium bed and the concentration of all released tritium (HT and TF) is monitored by the Ionization chamber A.

TF is captured in the molecular sieve bed and only the concentration of HT is monitored by the Ionization chamber B.

Cross Section of Monel (Ni70%-Cu30%) Sample container



The effect of the kind of container and tubing materials to the chemical form of tritium can be negligible, because the same results were obtained by the experiments using a SUS316 container and a Nylon tube instead of the Monel container and the Teflon tube.

Consistency in blanket system designs is required

