Activities on liquid blanket system in Japan

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US-Japan Workshop on
High Heat Flux Components and Plasma Surface Interactions for Next Fusion Devices
& High Power Density Devices and Designs

Port Townsend, Washington, July 28-31, 2003

Workshop Agenda

Research activities

on

1. Heat flux on the first wall
2. Tritium leakage in flibe system
3. MHD effects
4. TNT loop for molten salt

   & Task 1-1-B in JUPITER-II
5. Liquid related IFMIF, ITER-TBM

Reactor design activity in NIFS collaboration

• on going
cf. NIFS annual repo.

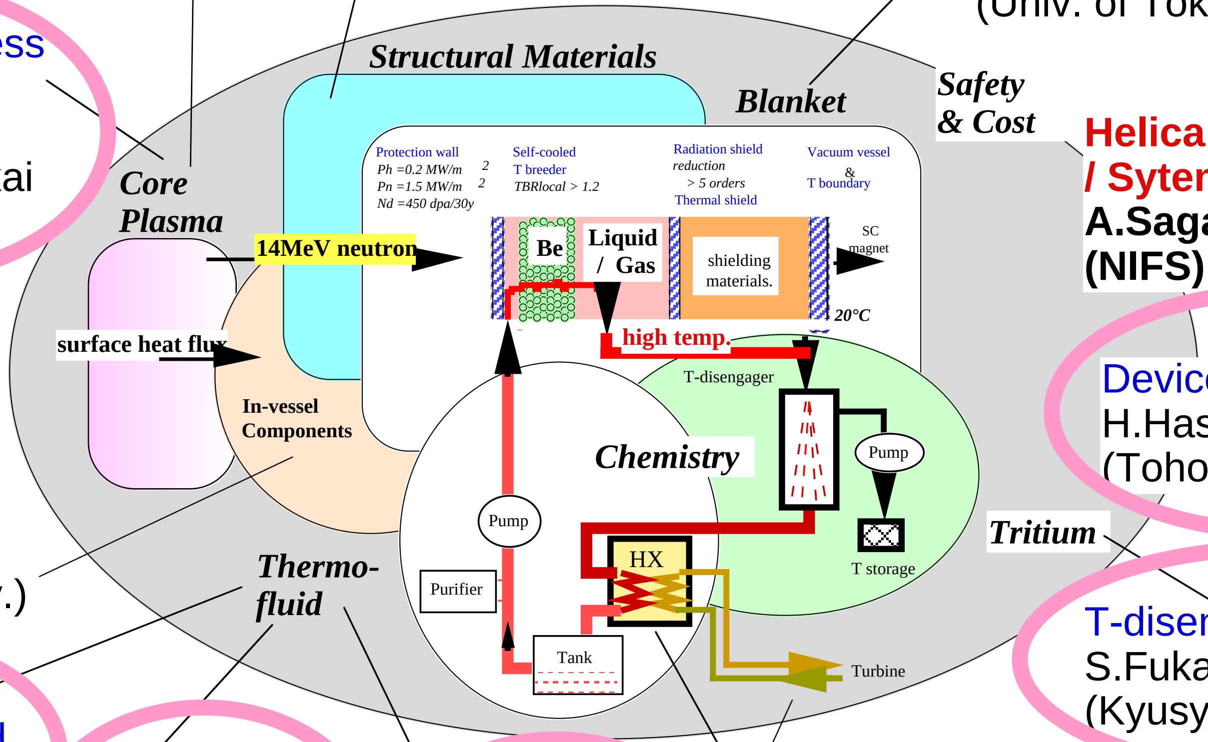
Helical core plasma
K.Yamazaki
(NIFS)

Thermo-mechanical analysis
H.Matsui
(Tohoku Univ.)

Blanket system
S,Tanaka
(Univ. of Tokyo)

Ignition access
& heat flux
O.Mitarai
(Kyusyu Tokai Univ.)

Helical reactor design / Sytem Integration
A.Sagara
(NIFS)



Device system code
H.Hashizume
(Tohoku Univ.)

Advanced
first wall
T.Norimatsu
(Osaka Univ.)

T-disengager system
S.Fukada, M.Nishikawa
(Kyusyu Univ.)

Advanced
thermofluid
T.Kunugi
(Kyoto Univ.)

Thermofluid
MHD
S.Satake
(Tokyo Univ. Sci.)

Thermofluid
system
K.Yuki
(Tohoku Univ.)

Heat exchanger & gas turbine system
A.Shimizu
(Kyusyu Univ.)

June 6. 2003, A.Sagara

Heat flux on the first wall
: toroidal effect

by O. Mitarai, *to be submitted & NIFS annual repo. 266(2002).*

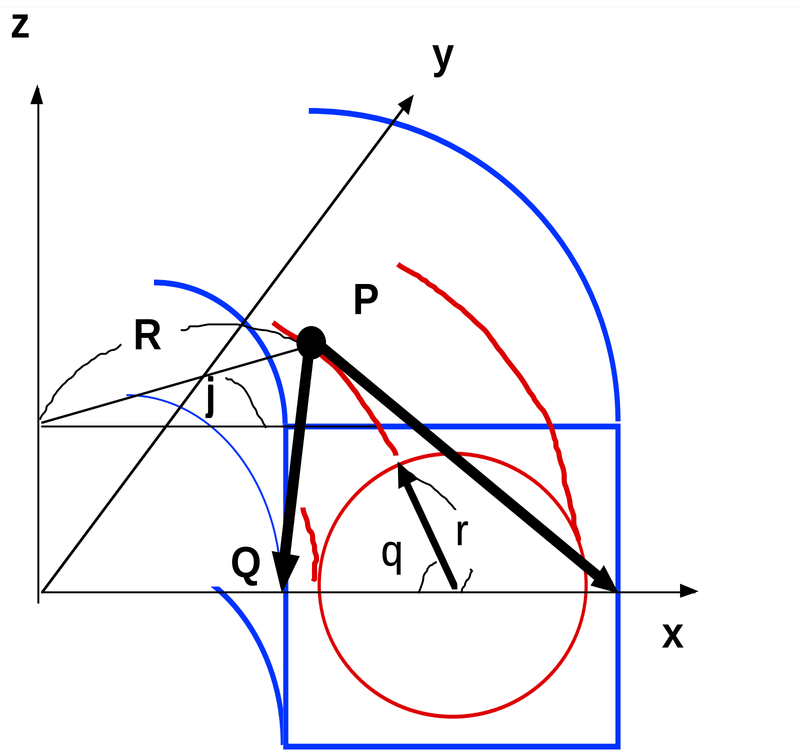
$$Q = \frac{\Delta P}{\Delta S} = \int_{V_p} P_b(\rho) \frac{\cos \psi}{4\pi \ell^2} dV_p$$

$$P_b(\rho) = P_b(0)\left[1 - \left(\frac{\rho}{a}\right)^2\right]^{2\alpha_n + 0.5\alpha_T}$$

$$P_b(r) \propto Z_{eff} n(r)^2 T(r)^{0.5} \quad \text{(bremss.)}$$

$$n(r) = n(0)(1-\{(R-R_0)/a\}^2)^{\alpha_n}$$

$$T_e(r) = T_e(0)(1-\{(R-R_0)/a\}^2)^{\alpha_T}$$



Toroidal coordinate

Fig. 6 Circular plasma and square vacuum chamber

HF ratio (out/in) is max 1.15 at A=2~3

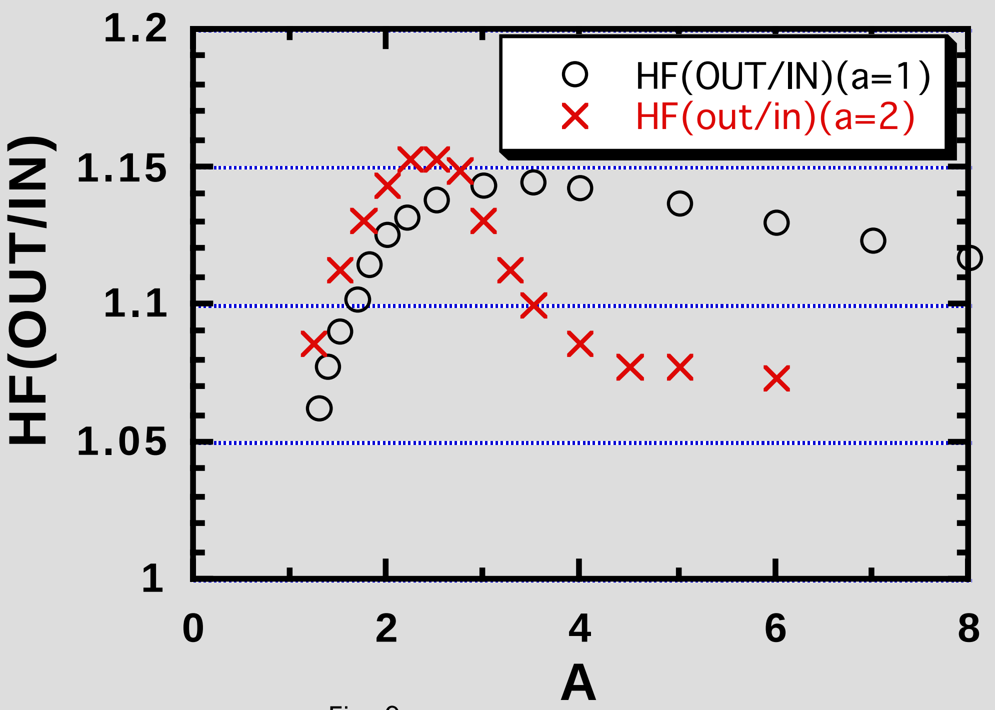


Fig. 9

In FFHR of A=10,
HF ratio (out/in) is less than 1.1
(cf. 1.22 in SSTR of A=4, ??).

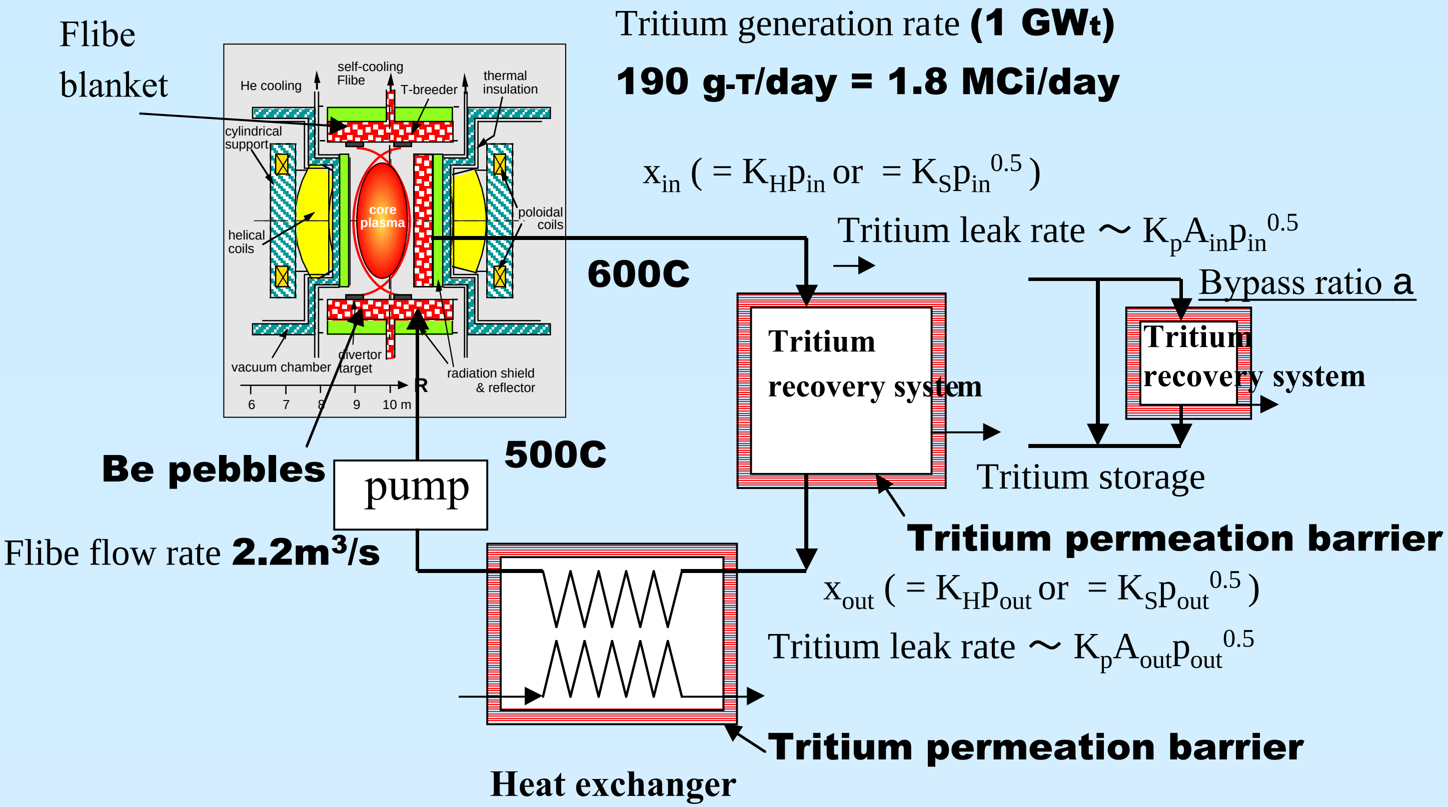
Averaged values

Parameters	FFHR-1	FFHR-2
major radius : R	20	10 m
av. plasma radius : $<a_p>$	2	1 m
toroidal field on axis : B_0	12	10 T
fusion power : P_f (GW)	3	1 GW
energy confinement time : τ_E	3.7	1.8 sec
av. plasma density : $<n_e>$	1E20	1.4E20 m^{-3}
av. plasma temperature : $<T_e>$	11	13.3 keV
alpha heating efficiency : η_α	0.7	0.7
synchrotron reflectivity : R_{eff}	0.9	0.9
hole fraction : f_h	0.1	0.1
synchrotron loss : Ps	0.05	0.039MW/m^2
Bremsstrhalung loss : P_B	0.04	0.046MW/m^2
Surface heat load : Pw	**0.09**	**0.09 MW/m^2**
neutron wall loading : Pn	1.5	1.7 MW/m^2
av. heat load on divertor : P_d	1.6	1.5MW/m^2
coil to plasma clearance : δL	1 .1	0.70 ~ 1.25 m
coolant flow rate (Flibe)	7	2.3 m^3/sec
coolant inlet pressure	0.6	0.6 MPa
coolant inlet temperature	450	450 C

Tritium leakage in flibe system

(by S. Fukada)

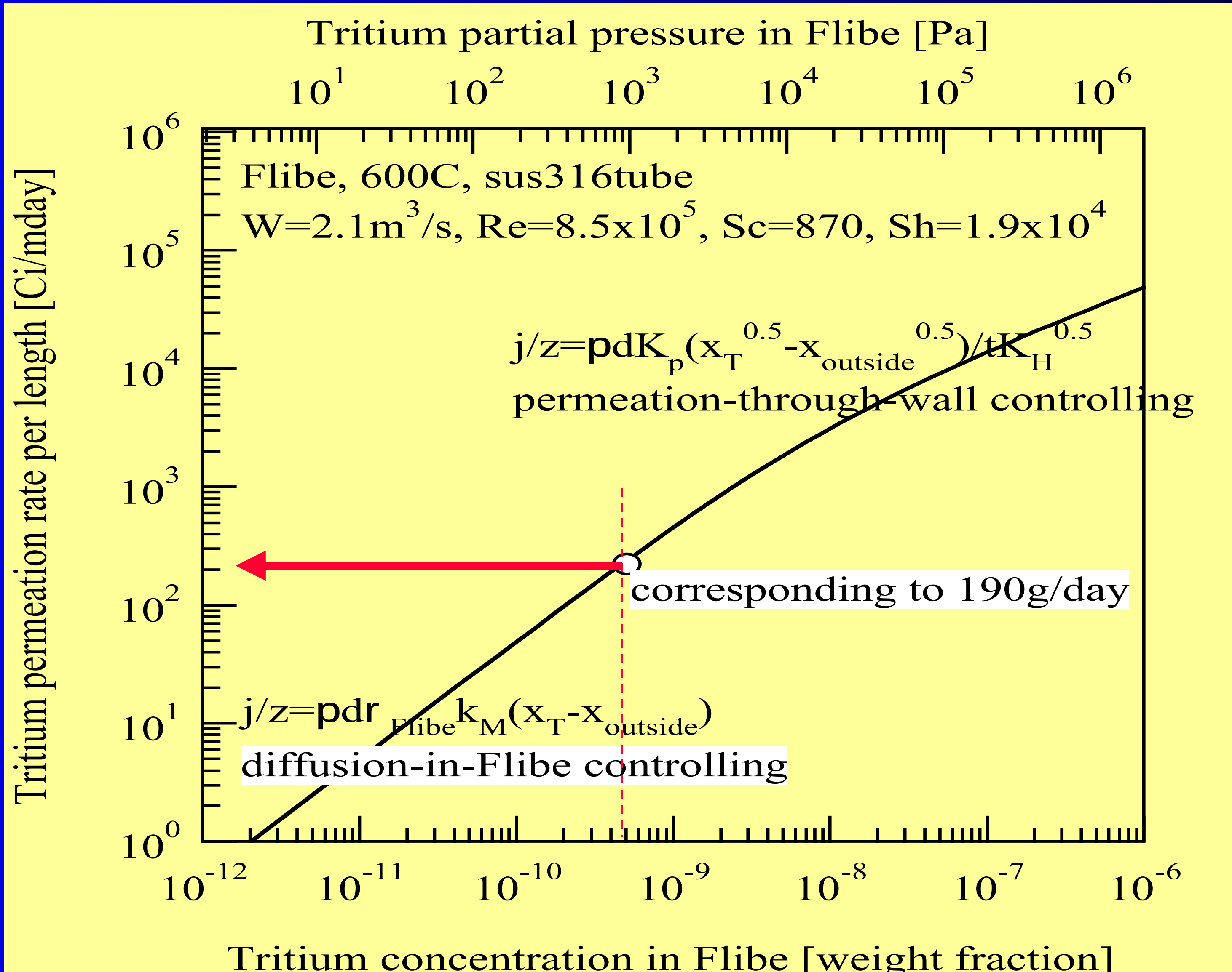
Flow of Flibe and tritium in FFHR-2



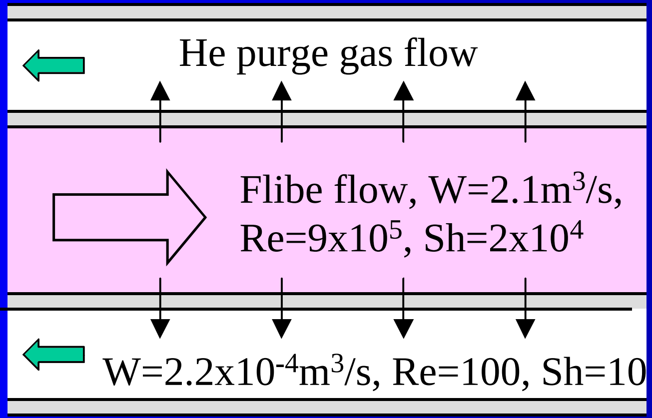
Tritium leak rate to the environment ∼**10 Ci/day**

$K_p A_{in} p_{in}^{0.5} + K_p A_{out} p_{out}^{0.5}$ + others

- W/O barrier, 200Ci/m/day from ss316 tube (t=5mm, f =0.7m)

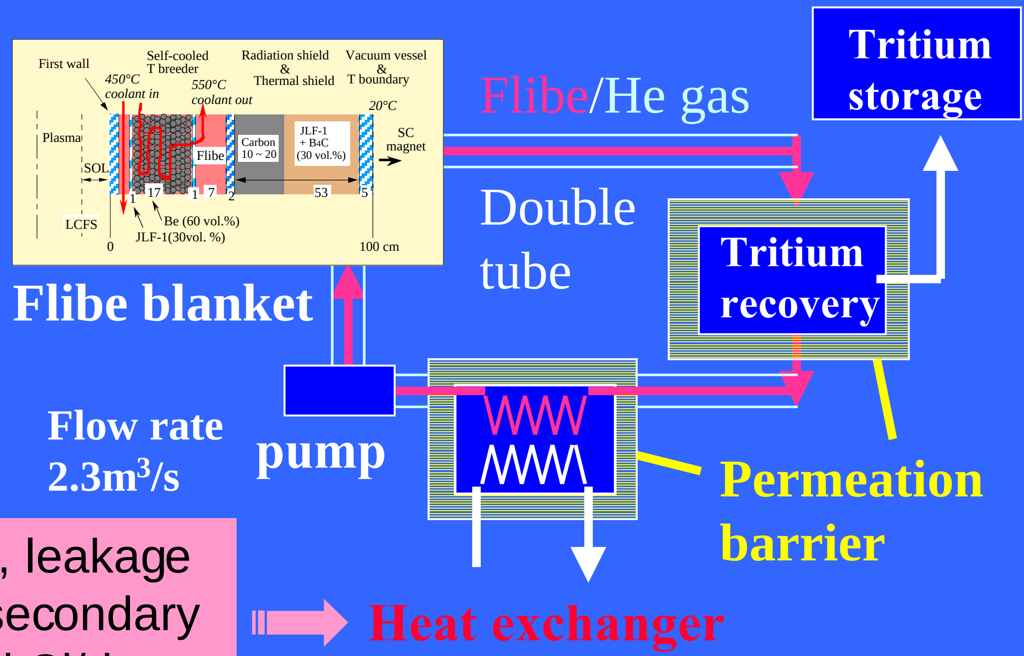


- With barrier of He sweep gas (W=220cc/s) and/or Flibe stagnant (t=0.5m) in double wall (100m^2), the leak level is 1.6Ci/day < 10Ci/day.



Tritium generation rate (1 GWt)

190 g-T/day = 1.8 MCi/day

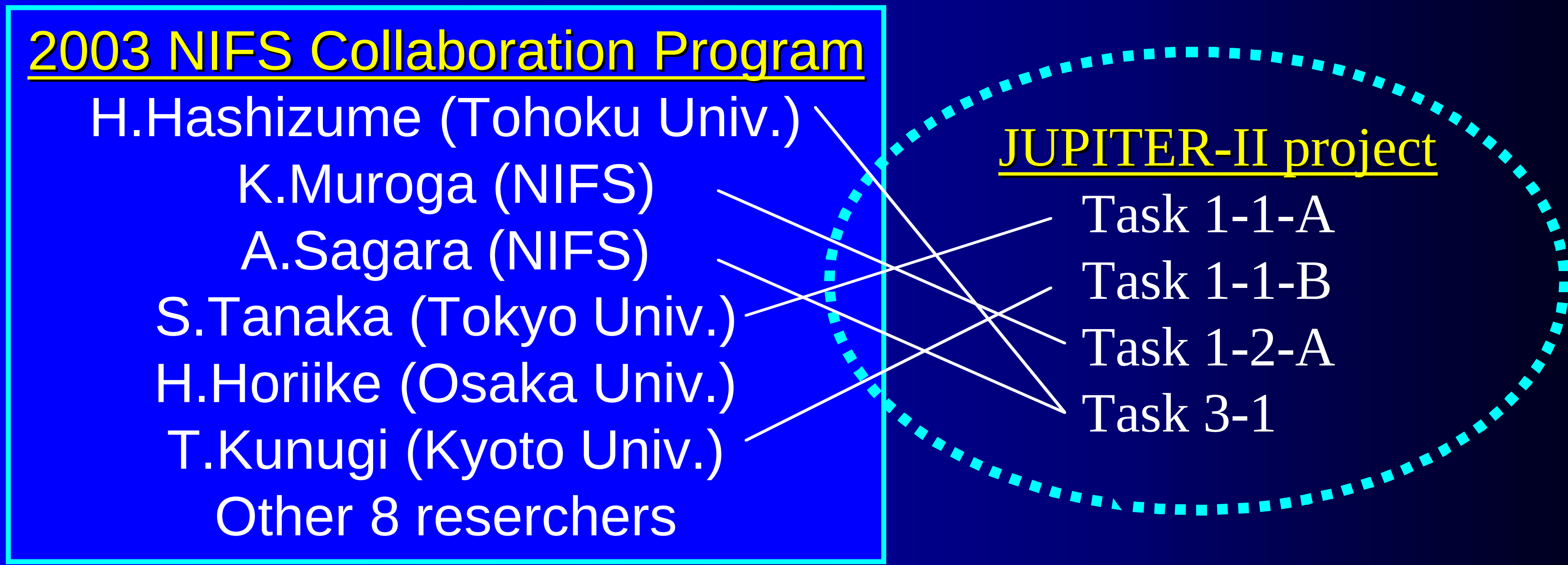


However, leakage into the secondary flow ~ 34kCi/day

	(1)a =1 (no by-pass)	(2)a =1 (Flibe barrier)	(3) a = 0.1
T generation rate in blanket	1,800kCi/day	1,800kCi/day	1,800kCi/day
T concentration in Flibe	5x10^{-4}wppm (1kPa)	5x10^{-4}wppm (1kPa)	5x10^{-3}wppm (10kPa)
In T recovery system	1,765kCi/day	1,766kCi/day	1,441kCi/day
T leak through line from blanket to TRS	**1kCi/day**	1Ci/day	**10kCi/day**
T leak through secondary flow	**34kCi/day**	**34kCi/day**	**340kCi/day**
T Leak from heat exchanger	10Ci/day	10Ci/day	**9kCi/day**
T leak through line from HX to blanket	10Ci/day	10Ci/day	**30Ci/day**
T inventory in sus 316	8kCi/ton	8kCi/ton	30kCi/ton

MHD effects

- **Evaluation method** **for degradation of the insulator, induced pressure increase.**
- **Proposing new method** **to reduce the MHD pressure increase.**
- **Clarification of feasibility** **for the liquid blanket system.**



Present status

- First discussion about the effect of crack existence on MHD pressure drop (April 22 at NIFS)
- Selecting the model and geometry to evaluate the MHD pressure drop with. (benchmark model)
- Numerical and analytical approaches will be performed till this August.

Thermo-fluid behavior of turbulent MHD flows in a liquid blanket

by S. Satake, *in NIFS Annual Repo. 2002-2003*

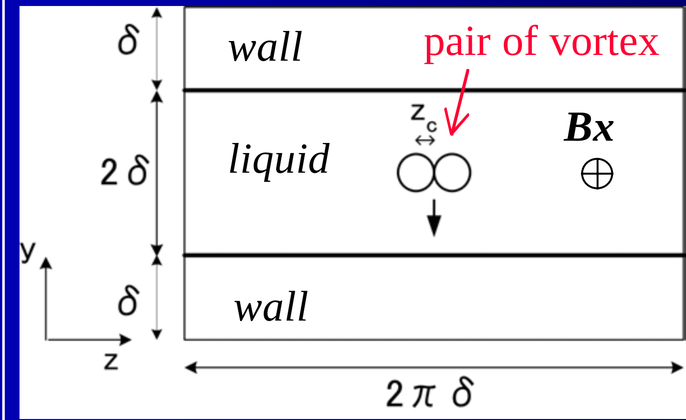
MOTIVATION

In the region of transition Reynolds numbers, the increase or decrease of **friction coefficients** of the coolant like a Molten Salt having a low electric conductivity is expected: a transition Hartmann number behavior. This behavior also may lead the deterioration of **heat transfer.**

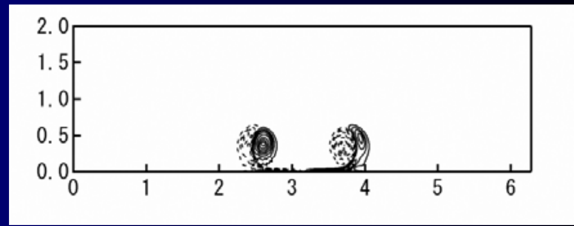
OBJECTIVES

The numerical analysis of the well-known “Vortex Dipole” problem under a magnetic field is performed in order to evaluate **the influence of an electrical conductivity of the first wall**.

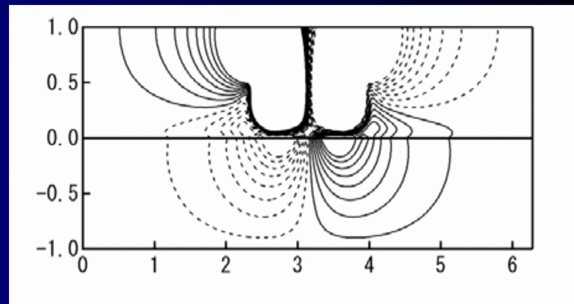
2D simulation



Hartmann number	*Ha* = 42
Conductivity	s = 0.1, 1, 100
Width *D*	d, 1/5d



Vortex distribution at t^*= 4 and s＝100



Electric potential at t^*= 4 and s＝100

In turbulence, energy loss increases in the parallel flow with *B*

Velocity profiles (*B*=10[T])

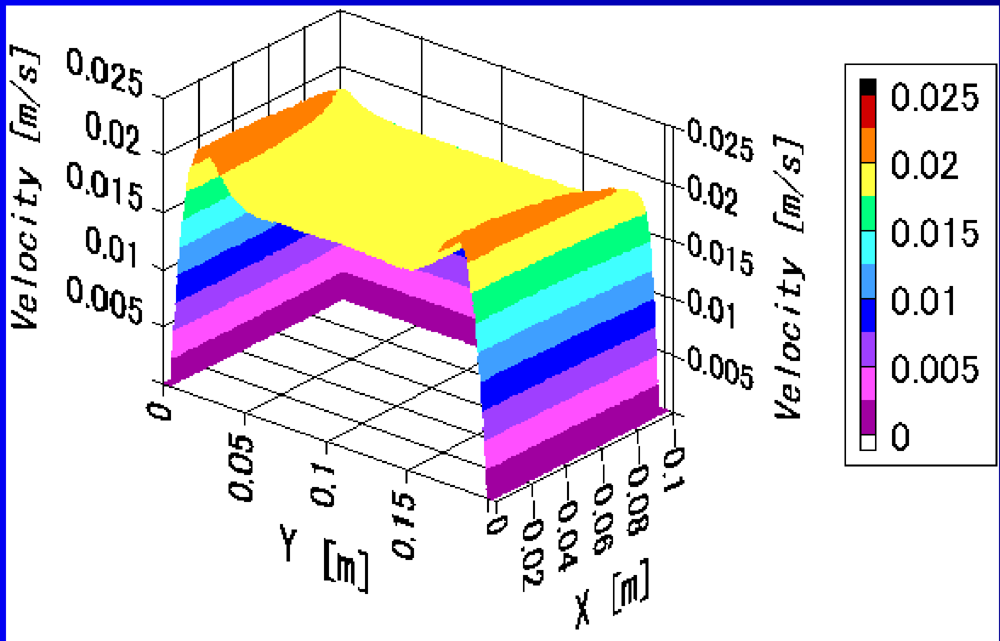
By H. Hashizume

[1] Flibe

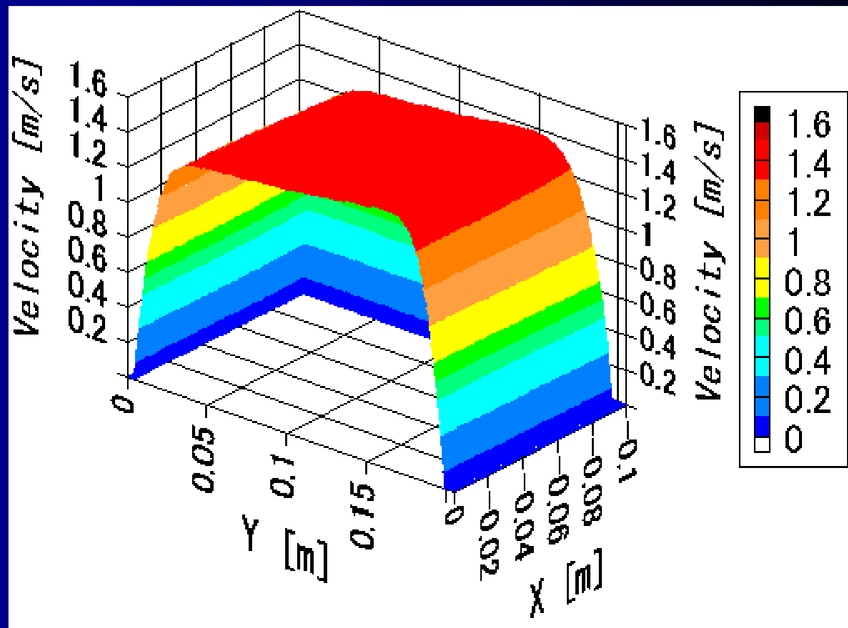
(a) Without Insulator

(b) Coated with Insulator

$$\sigma_i / \sigma_{HT9} = 10^{-9}$$



M-shape



Flat-shape

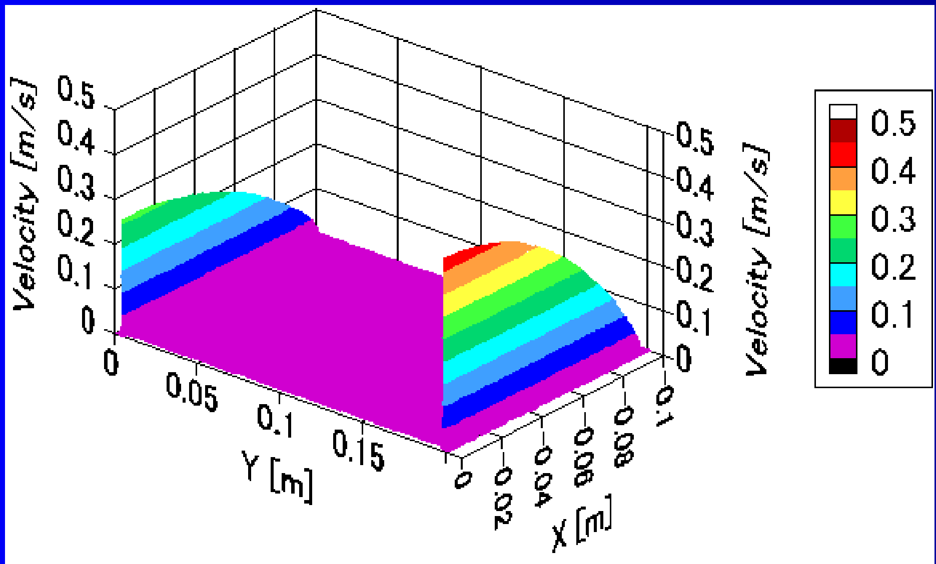
[2] Lithium

By H. Hashizume

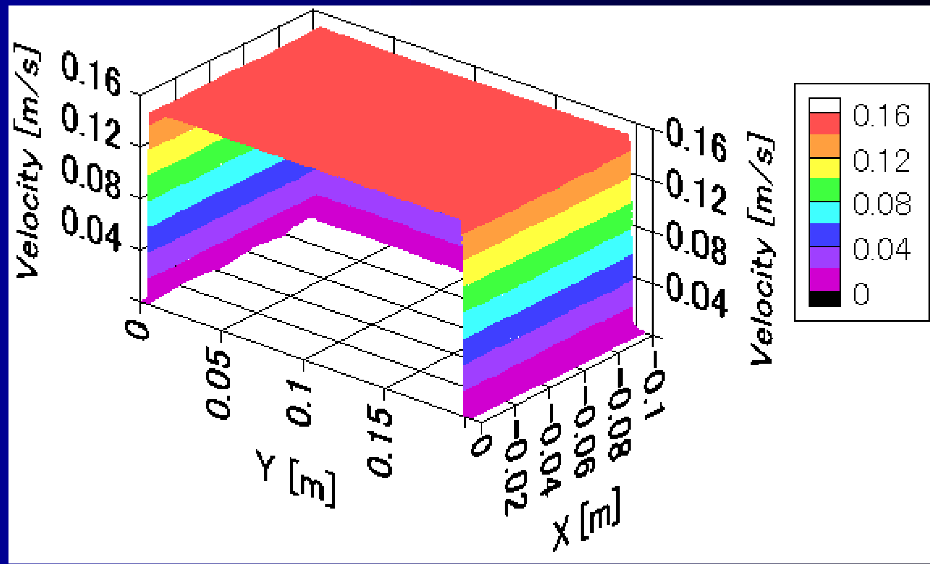
(a) Without Insulator

(b) Coated with Insulator

$$\sigma_i / \sigma_{HT9} = 10^{-9}$$

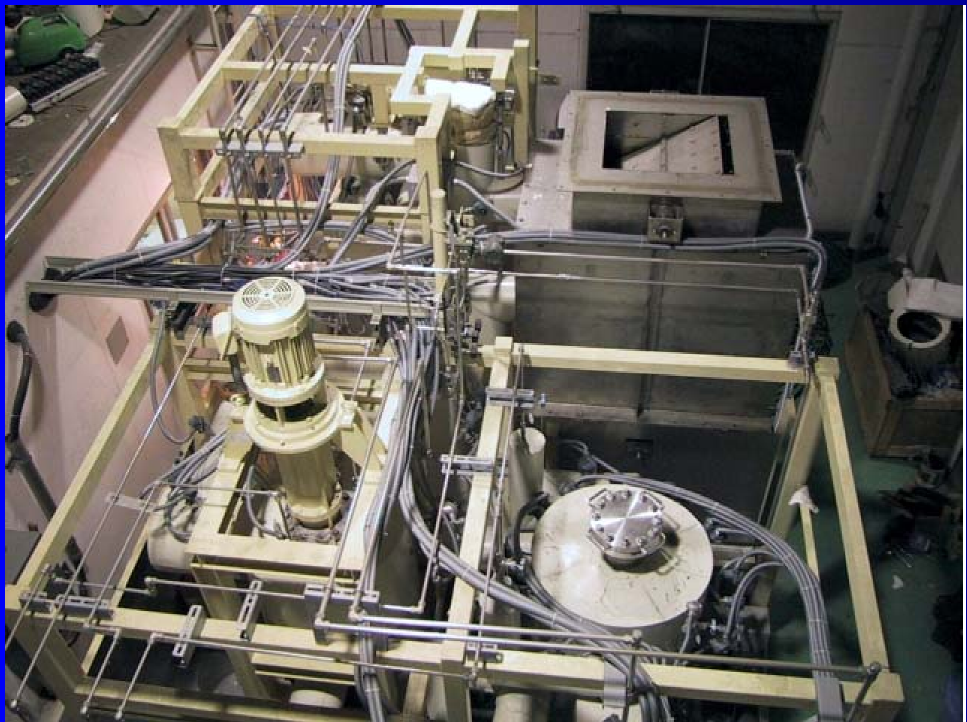


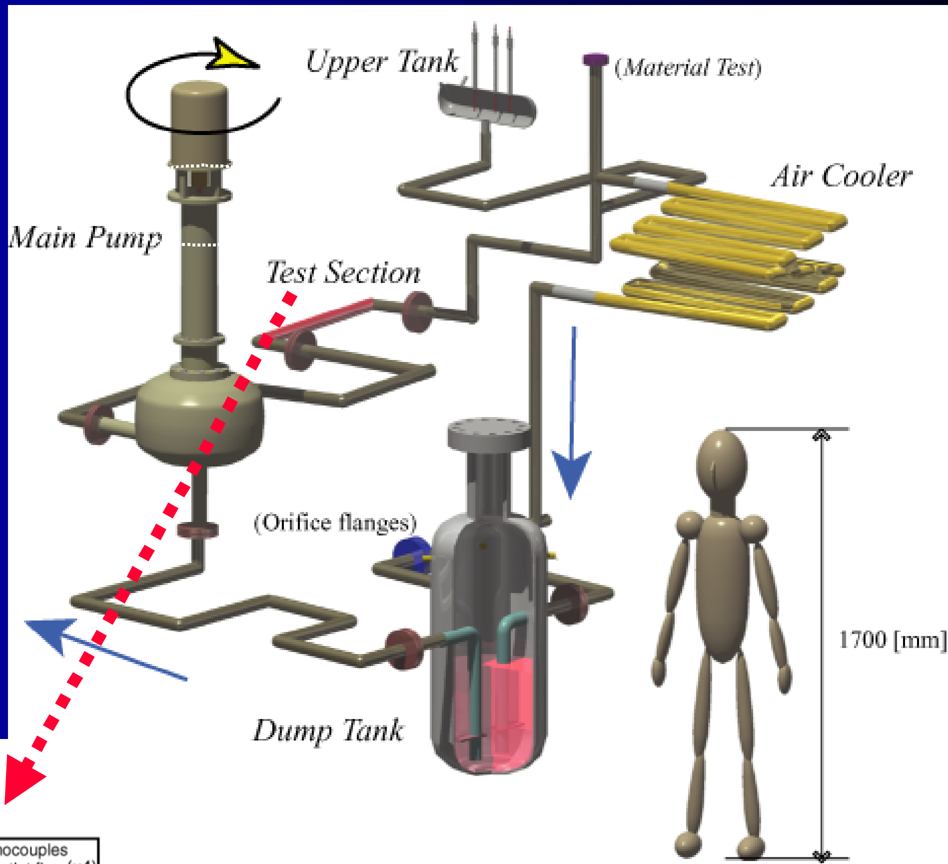
M-shape

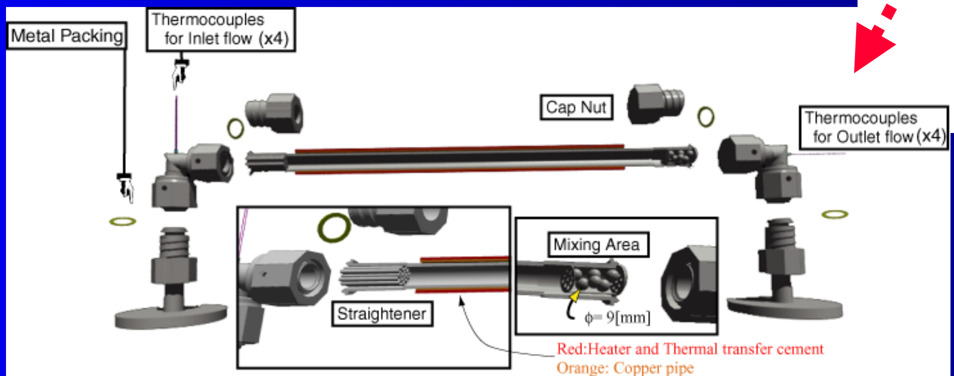


Flat-shape

Tohoku-NIFS Thermofluid loop for molten salt







Simulant for Flibe is used. (HTS: Heat Transfer Salt)

Heat transfer enhancer at low flow rate

… Packed-bed tube

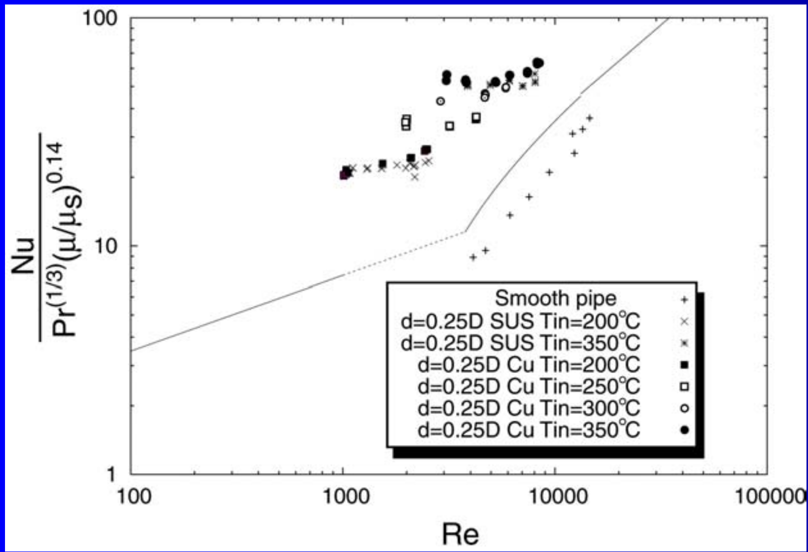
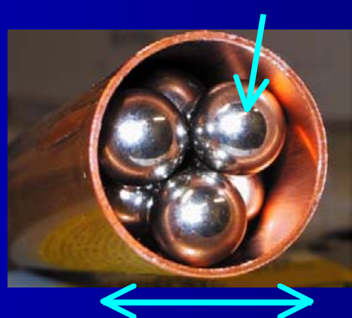
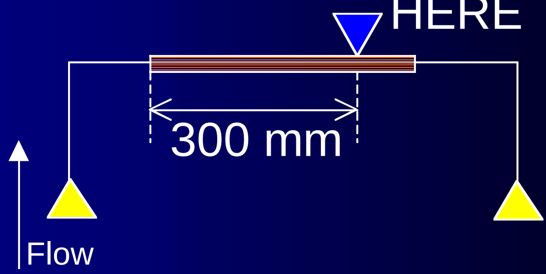


Fig.Re vs heat transfer characteristics (at 300 mm)





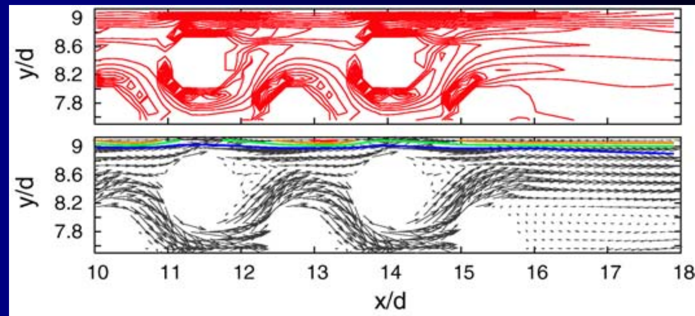


Fig. Flow structure near wall
(Result of 2D numerical simulation)

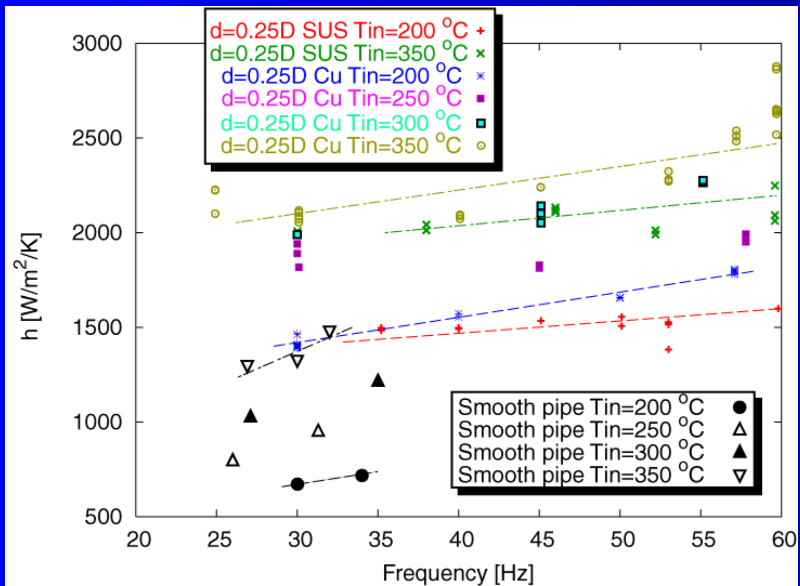


Fig.Pump frequency vs heat transfer coefficient (at 300 mm)

About **2** times higher than turbulent heat transfer

By S. Chiba and K.Yuki

<Plan of TNT loop>

- d=1/4D : Repacking beds: in order to research the effects of particle arrangement.

↓

- d=1/2D : Effect of particle diameter (SUS) + Repacking

↓

- d=1/2D or 1/4D : Effect of particle thermal conductivity (Zirconia is planned to be used) + Repacking

↓

After the experiments for packed-bed tube,

twisted-tape inserted tube is planned.

< at UCLA > --- JUPITER II project (Task 1-1-B)

Visualization and quantitative turbulence measurements for Flibe simulant

→ **FLI-HY-closed loop @ UCLA** : KOH circulating loop

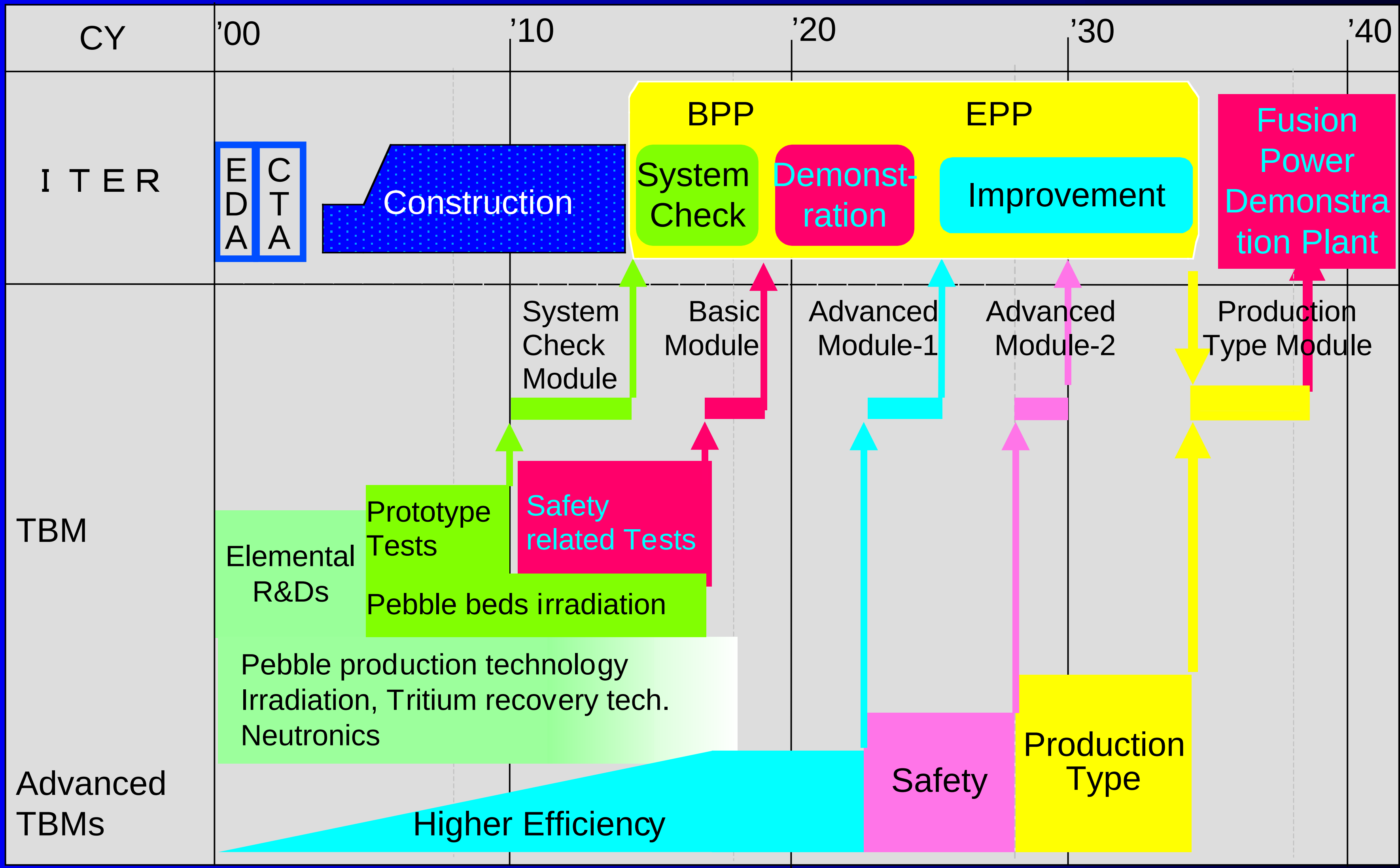
- ✓ The same parameter ranges and geometry as TNT loop (Re, Pr)
- ✓ Clarification of its thermofluid structure (flow and temperature fields)
- ✓ (with/without **Magnetic field**)
- ✓ Comparison with numerical simulation of Flibe Simulant (**Magnetic field**)

Recent Japanese Activity Relating with V/Li System

H.Matsui, T. Muroga

- IFMIF-KEP, Transition, EVEDA
  - Li free-surface tests to 15 m/s (Osaka-U)
  - Li purification with V and Cr alloys (U. Tokyo)
  - T-recovery (planned)
- Initiation of conceptual design effort for ITER-TBM application by Universities
  - NIFS-collaboration (Chaired by H. Matsui)
  - V/Li as reference and Flibe as back-up
  - Support from JAERI blanket team

TBM Schedule (proposed by JAERI)



Short-Term Schedules and Members

- Activity has started in December 13, 2002
- First output expected by March 2004

Workshop Agenda

Subject	University	NIFS	Initial Activity
Thermal-structural Analysis	Hashizume Horiike Takahashi	Imagawa Nagasaka	Thermal-structural analysis MHD-reduction
Neutronics	Iguchi	T. Tanaka	T-production Nuclear Heat, After Heat, Activation
T-recovery	S. Tanaka Fukada	Suzuki	Hot trap Cold trap
Materials	Matsui Abe	Nagasaka	Design data
Flibe-module concept	Terai	Sagara	Concept exploration
Design Integration	Matsui JAERI	Muroga Sagara	Reporting