R&D activities on flibe blanket in Japan

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Molten salt R & D activities in Japan

- FFHR design
- with R&D

R&D/LHD
- TNT loop
- Ultrahigh HT

- JUPITER-II

Advantages in LHD
- current-less
- Steady state
- no CD power
- Intrinsic divertor

**Force Free Helical Reactor**

**Phase I ----- Concept definition**
- 1993 Design of FFHR-1 \((I=3)\)
- 1994 \(\longrightarrow\) NIFS Collaboration
- 1995 Design of FFHR-2 \((I=2)\)
- 1998 \(\longrightarrow\) Fusion Eng. Network
- 2001 \(\longrightarrow\) Liq. Blanket in **JUPITER-II**
- 2002 \(\longrightarrow\) Concept improvements
FFHR
Design Concept
& Optimization

Enhancing inherent safety & Thermal efficiency
Molten-salt blanket with low MHD effect

- Plasma
- JLF-1(30vol. %)
- Be (60 vol.%)
- JLF-1 + B4C (30 vol.%)

Self-cooled T breeder
Radiation shield
Vacuum vessel

Simplification of supporting structure
Reduction of magnetic force
Expansion of blanket area
Heat transfer & structure materials
MHD stability

Continuos winding helical coil

High B design

issue
SC materials & Current density

Gamma = (m a_c / l R)

Reduction of magnetic force
Continuos winding helical coil

Heat transfer & structure materials

Expansion of blanket area

issue

MHD stability

Reduction of magnetic force
Continuos winding helical coil

Heat transfer & structure materials

Reactor design activity in NIFS collaboration

- **Helical core plasma**
  - K.Yamazaki (NIFS)

- **Ignition access**
  - O.Mitarai (Kyusyu Tokai Univ.)

- **Advanced first wall**
  - T.Norimatsu (Osaka Univ.)

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

- **Blanket system**
  - S.Tanaka (Univ. of Tokyo)

- **Thermo-fluid**
  - S.Satake (Tokyo Univ. Sci.)
  - K.Yuki (Tohoku Univ.)

- **Thermal shield**
  - 20°C

- **Vacuum vessel**
  - T boundary

- **Protection wall**
  - Ph = 0.2 MW/m

- **Thermo-fluid system**
  - A.Shimizu (Kyusyu Univ.)

- **Heat exchanger & gas turbine system**
  - A.Sagara (NIFS)

- **Device system code**
  - H.Hashizume (Tohoku Univ.)

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

- **In-vessel Components**

- **Structural Materials**

- **Shielding materials**

- **14MeV neutron**

- **Surface heat flux**

- **Liquid / Gas**

- **T-disengager**

- **T storage**

- **Pump**

- **Purifier**

- **HX**

- **Turbine**

- **Fuel element**

- **Core Plasma**

- **Safety & Cost**

- **Chemistry**

- **Flibe related**

- **on going**
  - cf. NIFS annual repo.

- **Helical reactor design**
  - / System Integration
  - A.Sagara (NIFS)

- **Reactor design activity in NIFS collaboration**

**June 6, 2003, A.Sagara**
Evaluation of tritium leak and permeation barrier
(by S. Fukada)

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

- With barrier of He sweep gas (W=220cc/s) and/or Flibe stagnant (t=0.5m) in double wall (100m²), the leak level is 1.6Ci/day < 10Ci/day.

\[
\text{Tritium permeation rate per length [Ci/m/day]} \quad 10^{-12} \quad 10^{-11} \quad 10^{-10} \quad 10^{-9} \quad 10^{-8} \quad 10^{-7} \quad 10^{-6}
\]

Tritium concentration in Flibe [weight fraction]

\[
\text{Tritium partial pressure in Flibe [Pa]} \quad 10^1 \quad 10^2 \quad 10^3 \quad 10^4 \quad 10^5 \quad 10^6
\]

He purge gas flow

Flow rate 2.3m³/s

W=2.2x10⁻⁴m³/s, Re=100, Sh=10

W=2.1m³/s, Re=8.5x10⁵, Sc=870, Sh=1.9x10⁴

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

Tritium generation rate (1 GWt)
190 g-T/day = 1.8 MCi/day

Flibe/He gas

Double tube

Tritium storage

Flibe blanket

Tritium recovery

Flow rate 2.3m³/s

pump

Permeation barrier

Heat exchanger
Permeation window system for Tritium Recovery

With the barrier for T leakage, operation at \( C_T > 0.3 \text{ppm} \) (\( P_{T_2} \approx 20 \text{ kPa} \)) is optimum.

Recovery systems of a realistic-scale (the total < a few 100 \( \text{m}^2 \)) are possible for permeation window disengager systems.

Diffusion of \( T_2 \) in Flibe is the rate-limiting process.

Japan-US joint project **JUPITER-II**
From FY2001 to 2006

- **1-1-A**: FLiBe Handling/Tritium Chemistry
- **1-1-B**: FLiBe Thermofluid Flow Simulation
- **2-2**: SiC System Thermomechanics
- **3-1**: Design-based Integration Modeling
- **3-2**: Materials Systems Modeling
- **1-2-A**: Coatings for MHD Reduction
- **1-2-B**: V Alloy Capsule Irradiation
- **2-1**: SiC Fundamental Issues, Fabrication, and Materials Supply
- **2-3**: SiC Capsule Irradiation
1. Development of the Molten Salt Forced Circulation Loop Unit and Investigation on the High Heat Flux Removal Device for Divertor and Blanket Technologies

Tohoku Univ., Prof. S. Toda / A. Sagara (NIFS) (FY1997 - 2000 - )

2. Ultrahigh Heat Transfer Enhancement using Nano-Particle Porous Surface for Divertor and Blanket Technologies

Kyoto Univ., Prof. T. Kunugi / A. Sagara (NIFS) (FY2004 - 2006 - )

July 4, ‘03

“2 times enhanced by Kunugi”
Tohoku-NIFS Thermofluid loop for molten salt

TNT loop

- $u \sim \text{Max.20 L/min}$
- $T \sim 600^\circ\text{C}$
- $V \sim 0.1\text{m}^3$
- $P \sim 0.7\text{ MPa}$

Now HTS (simulant for Flibe) is used.

• M.Omae, “Experimental study about heat transfer enhancement for high temperature molten salt”, Master thesis of Tohoku Univ. (2003) [In Japanese]


System diagram of TNT loop
Bird’s eye view of TNT loop

Control Room

Upper Tank

Test Section

Main Pump

Air Cooler

Dump Tank

(Fabricated by IHI Co., Ltd.)
Side view of TNT loop

Main Pump
Upper Tank
Air Cooler
Dump Tank
Elapsed time vs Temperature at each point of TNT loop (Heater Test)

Elapsed time (hr)

Temperature (°C)
Thermal insulator at Test Section and Schematic view of cross section
Heat transfer enhancer at low flow rate

... Packed-bed tube in TNT loop

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

About 3 times higher than turbulent heat transfer

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

Fig. Pump frequency vs heat transfer coefficient (at 300 mm)
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Presented by A. Sagara (NIFS), Feb.’04


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• JUPITER-II

• ITER-TBM

Presented by A. Sagara (NIFS), Feb.’04