Overview of Research and Development Activities on Fusion Nuclear Technologies in Japan

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The University of Tokyo
Outline

• Introduction
• FNT Research and Development Program of Japan
• Development of Breeding Blankets
  Solid Breeding Blankets
  Liquid Breeding Blankets
• R&D on other FNT Issues
  PMI
  Fuel Processing System
  Safety
  Reactor Design Study
• Summary
Increasing energy demand in 21st century, especially in Asia with larger population and economic growth.

- Shortage of resources: oil and natural gas

- Environmental problem.
Energy resources problem and role of fusion (2)

- Nuclear energy and new energy are required
- Energy also for Hydrogen Production
- Limitation in New Energy

1000MWe by solar
Limitation by new energy

- In the latter half of the 21st century, fast breeding reactor is an important choice
- Potential hazards of high level waste and plutonium in FBR

Fusion reactor should be a powerful competitor.
Introduction (3)

Energy resources problem and role of fusion (3)

Future Energy in the world

Fusion energy should be one of the candidates in the latter half of the 21st century.

For this, DEMO reactor should be realized well in advance of the middle of the 21st century.

Timely ITER construction and operation are vitally important.
Introduction (4)
Roadmap towards Fusion Energy Utilization

Large Tokamaks
(e.x.; JT-60)

ITER

DEMO

- Non-nuclear
- Physics Exp.
- Plasma Tech.

- First Nuclear Tokamak
- Exp.of Burning Plasmas integrated with Key Reactor Technologies
- Integrated Testing of

Materials Devel., IFMIF

- Large-scaled Power Generation
- Steady-state Operation

ITER is an essential facility for fusion energy in Japan, in Asia and in the World.

- The world Fusion program is now opening a new era for operation and utilization of ITER.
- FNT is essential in “nuclear machine ITER” and for DEMO.
- FNT is essential for realizing fusion energy in the world.
FNT R&D Program of Japan (1)
FNT research as part of the 3\textsuperscript{rd} Phase Basic R&Ds Program

Final goal of the 3\textsuperscript{rd} Phase Basic R&Ds Program
- Achievement of self ignition conditions
- Realization of long term burning
- Development of FNTs essential to DEMO reactors

Development of Tokamak type experimental reactor (ITER) as a center facility

Ad hoc working group of MEXT discussed future direction (10-20 years) of national fusion program.

Report issued in January 2003

In addition to ITER, focus on domestic fusion researches on highest priority areas:
- Tokamak : JT-60
- Helical : LHD
- Laser : GEKKO-XII

FNT Research, including IFMIF-EVEDA

Strengthen domestic and international collaborations
Foster young and talented researchers
FNT R&D program of Japan (2)
Implementation Scheme of FNT R&D in Japan

International Collaborations
- ITER
- IEA
  - Fusion Reactor Tech.
  - Fusion Materials
  - Safety

Bi-laterals
- US, EU, RF, KO, CN, etc,

R&Ds directly related to ITER and DEMO

Universities / NIFS

Fundamental Studies, R&Ds for higher performances and challenging options

JAERI

AESJ/FED, JSPF, Fusion Forum, FT Network

Supporting Technology

Policy Making

AEC

CSTP

Administration Branch

MEXT

Working Group: future direction of national fusion research

JAPAN

R&D Activities

Industries

AEC : Atomic Energy Commission of Japan
CSTP : Council for Science and Technology Policy of Japan
MEXT : Ministry of Education, Culture, Sports, Science and Technology
AESJ : Atomic Energy Society of Japan
JSPF : Japan Society of Plasma Science and Nuclear Fusion Research
FNT R&D program of Japan (3)
FNT R&D sites in Japan

Chugoku/Shikoku area
Okayama Univ.
Hiroshima Univ.
Yamaguchi Univ.
Tokushima Univ.
Total 18 Institutes

Hokuriku area
Toyama Univ.
Kanazawa Univ.
Fukui Univ.
Total 8 Institutes

Hokkaido area
Hokkaido Univ.
Total 5 Institutes

Tohoku area
Iwate Univ.
Tohoku Univ.
Total 8 Institutes

Kanto/Koshin area
Ibaraki Univ.
Tsukuba Univ.
The Univ. of Tokyo
Tokyo Inst. of Tech.
Yokohama Int’l Univ.
Niigata Univ.
Tokai Univ.
Nihon Univ.
KEK
JAERI
Total 65 Institutes

Chubu area
Shizuoka Univ.
Nagoya Univ.
Mie Univ.
Chubu Univ.
NIFS
Total 20 Institutes

Kyushu area
Kyushu Univ.
Saga Univ.
Nagasaki Univ.
Kumamoto Univ.
Ryukyu Univ.
Total 16 Institutes

Kinki area
Kyoto Univ.
Osaka Univ.
Kobe Univ.
Total 18 Institutes

Gamma10 (Mirror)
Tsukuba Univ.

LHD (Helical)
NIFS

CHS (Helical)
NIFS

Gekko (Laser)
Osaka Univ.

Heliotron J (Helical)
Kyoto Univ.

TRIAM-1M (Tokamak)
Kyushu Univ.

Takahoko Lake
Obuchi Lake
National Oil Storage Site
(brackish water)
(freshwater)

Mutsu Ogawara Port
5000 t (DWT)
Wharf
2000 t (DWT) Wharf

Transportation routes

Nuclear Fuel Cycle Facilities

Plan of new routes

Route 338
Pacific Ocean

ITER Site
ITER candidate site

ITER candidate site

National Laboratories : 300
Universities : 600
Industries : 100

FNT population
FNT R&D program of Japan (4)

Fusion Nuclear Technologies in ITER

ITER

Integrated testing of DEMO blankets on:
- tritium breeding;
- high-grade thermal power extraction and electric power generation;
- radiation shielding.

FNT essential for DEMO largely developed in ITER in an integrated manner, typically, on:
- safe and reliable operation of large-scaled tritium fuel processing system;
- sufficient radiation shielding by blankets to assure sound operation of SC magnets;
- reliable and long-lived PFCs against high heat and particle loads.

ITER is an important milestone for FNT in Japan
JAERI, in collaboration with universities and industries, has been contributing to design refinement and preparations for procurement and operation.
**FNT R&D program of Japan (6)**

**Licensing Preparation for ITER**

**2002 November**

Ministry of Education, Culture, Sports, Science and Technology (MEXT) summarized a report “Basic Policy of ITER Safety Regulation”.

**Outline of “Basic Policy of ITER Safety Regulation”**

1. **Procedure and Items to be confirmed**
   - Items before start of construction.
   - Items before start of use.
   - Regulation at operation phase
   - Submission of document for confirmation of safety measures related to dismantling, disassembly, waste processing, etc.

2. **Technical requirements**
   - Requirements for safety functions and methods of safety assessment
   - Requirements for basic safety performance of assembly
   - Requirements and codes & standards for main design specification

3. **Areas and items to be confirmed in detailed design and those of inspections**
   - Items of regulatory confirmation on design and construction of the ITER facility (Table)

MEXT can conduct site-specific licensing process immediately.
Japan is investigating all fields of FNT for ITER and DEMO.
Development of Breeding Blanket
R&D configuration for breeding blanket development

Development of breeding blanket

<table>
<thead>
<tr>
<th>Reference blanket</th>
<th>Advanced options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid / Water</td>
<td>Solid / He</td>
</tr>
<tr>
<td>Liquid or molten salt</td>
<td></td>
</tr>
</tbody>
</table>

ITER TBM    DEMO

Engineering R&D  Engineering R&D

Support

JAERI

NIFS / Universities

ITER TBWG

IEA

NIFS Collaboration Program
JUPITER-II with US-DOE
Japan-China Collaboration Program
Japan-Korea Collaboration Program etc.
Milestones to the fusion power demonstration plant
(1) By ITER TBM testing, demonstrative data of blanket functions will be obtained in fusion environment.
(2) Together with the material irradiation data by IFMIF, the construction of the blanket of fusion power demonstration plant will be decided.
# Development of Breeding Blankets (2)

## Development Schedule of Solid Breeding Blanket for ITER TBM

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Fusion Power Demonstration Plant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ITER Project</strong></td>
<td>EDA</td>
<td>CTA/ITA</td>
<td>Construction</td>
<td>Operation</td>
<td>TBM Tests</td>
</tr>
<tr>
<td><strong>Blanket Development Phase</strong></td>
<td>Elemental Technology</td>
<td>Engineering R&amp;D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Test Blanket Fabrication</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Blanket R&amp;D</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>• Out-pile R&amp;Ds</strong></td>
<td>Elemental R&amp;Ds on Fabrication Tech.</td>
<td>Engineering R&amp;Ds with large scale mock-ups</td>
<td>Out-pile overall Demonstration Tests</td>
<td></td>
<td>Out-pile Overall Demonstration Tests of Advanced Module</td>
</tr>
<tr>
<td><strong>• In-pile R&amp;Ds</strong></td>
<td>Elemental R&amp;Ds on Irradiation Tech.</td>
<td>Engineering R&amp;Ds on Irradiation Tech., Pebble Fabrication Tech.</td>
<td>Irradiation Tests on Module #2</td>
<td>Irradiation Tests on Advanced Module</td>
<td></td>
</tr>
<tr>
<td><strong>• Neutronics / Tritium Production Tests with 14MeV neutrons</strong></td>
<td>Basic Research on Blanket Neutronics</td>
<td>TPR evaluation with simulated blanket structure</td>
<td>TPR Evaluation with a full module structure</td>
<td>TPR Evaluation with a Full Structure of Advanced Module</td>
<td></td>
</tr>
<tr>
<td><strong>• Tritium Recovery System Development</strong></td>
<td>Basic Research on Blanket Tritium Recovery Process</td>
<td>Elemental R&amp;Ds</td>
<td>Prototype Development</td>
<td>Overall system Tests</td>
<td>Overall system Tests for Advanced Module</td>
</tr>
<tr>
<td><strong>Structural Material R&amp;D (RAF/M)</strong></td>
<td>Optimization</td>
<td>Verification</td>
<td>Qualification/Improvement</td>
<td>Radiation in Fission Reactors</td>
<td>IFMIF</td>
</tr>
</tbody>
</table>
Development of Breeding Blankets (3)

Development of water cooled solid breeding blanket (1)
Overview of design and R&Ds

- **System Integration, Off-pile R&D**
  - Module fabrication technology
  - Thermo-mechanical integrity of module
  - Thermo-mechanical performance
  - Thermal hydraulic research

- **In-pile R&D**
  - Breeder/multiplier development
  - Irradiation technology development
  - Irradiation tests of blanket partial mockup

- **Tritium Recovery System Development**
  - Process and system development for hydrogen pump, coolant water detritiation system

- **Neutronics / Tritium Production Tests with 14MeV neutrons**
  - Neutronics performance of blanket mockup and improvement of analysis accuracy

- **Material Development**
  - Irradiation data of RAFM (F82H), etc.
  - Environmental effect, etc.

- **Fusion Reactor Design**
  - DEMO2001
  - First Wall
  - Breeder/multiplier bed layers

- **Solid Breeder Blanket**
  - (layered pebble beds, water cooled)
As a key fabrication technology for blanket structure, hot isostatic pressing (HIP) bonding method was proposed and its optimum condition was preliminarily investigated.

HIP and post HIP heat treatment conditions have been optimized.

→ HIP at 1150 °C + PHHT at 930 °C + Tempering
Development of Breeding Blankets (5)
Development of water cooled solid breeding blanket (3)
Achievement of In-pile R&D

Li$_2$TiO$_3$ Pebble Bed (binary)
(packing fraction : 81.3%)

Larger Pebbles
(~φ1.9 mm av.)

Small Pebbles
(~φ0.27 mm av.)

Neutron Flux Change

Effect of Neutron irradiation on Effective Thermal Diffusivity

R/G=1

The overall tritium recovery behavior under the ITER pulse mode was almost the same as the behavior under the constant mode.

Tritium Release behavior under ITER Pulse Mode

Ratio of tritium release and generation (R/G)

Elapsed time (h)

R/G=1

The overall tritium recovery behavior under the ITER pulse mode was almost the same as the behavior under the constant mode.

Effect of Neutron irradiation on Effective Thermal Diffusivity

Effective thermal diffusivity Obtained by out-pile test (M. Enoeda)

JMTR
Development of Breeding Blankets (6)

Development of water cooled solid breeding blanket (4)

R&Ds on Tritium Recovery System and Blanket Neutronics

Tritium Recovery System Development (Electrochemical Hydrogen Pump)

Neutronics / Tritium Production Tests with 14MeV neutrons

Ionic hydrogen transportation property was clarified.

The calculation results agree well with the experimental data within 2 and 11% for the campaigns without and with the reflector.
Development of Breeding Blankets (7)

Development of water cooled solid breeding blanket (5)

R&Ds on functional materials for blanket

**Tritium Breeder Material**
- Elemental fabrication technology of $\text{Li}_2\text{TiO}_3$ was established.
- Oxide-doped $\text{Li}_2\text{TiO}_3$ is to be selected as an advanced material.
- Control of grain size  - Chemical stability

1) Pebble Fabrication Development
- Success in fabrication of $^6\text{Li}$-enriched (30 and 95at%) $\text{Li}_2\text{TiO}_3$ pebbles and TiO$_2$-doped $\text{Li}_2\text{TiO}_3$ pebbles by indirect wet process.

**2) Characterization**

- Fabrication method: wet process

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>TiO$_2$-doping</th>
<th>Density (% T.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>Un-doped</td>
<td>90</td>
</tr>
<tr>
<td>600</td>
<td>Un-doped</td>
<td>80</td>
</tr>
<tr>
<td>700</td>
<td>5mol%</td>
<td>80</td>
</tr>
<tr>
<td>800</td>
<td>5mol%</td>
<td>80</td>
</tr>
<tr>
<td>900</td>
<td>5mol%</td>
<td>80</td>
</tr>
<tr>
<td>1000</td>
<td>5mol%</td>
<td>80</td>
</tr>
</tbody>
</table>

- Sweep gas: Ar+0.1%H$_2$

**H$_2$ reaction rate**

- H$_2$ reaction rate is small

**Grain size**
- Target value: < 5 µm

**Fabrication Process**
- Starting powder ($\text{Li}_2\text{TiO}_3$, oxide)
- Supporter (PVA, etc)
- $\text{H}_2\text{O}$
- Gel-spheres
- Coagulant
- Mixing
- Dropping
- Aging
- Drying/Calcination/Sintering

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**Development of Breeding Blankets (8)**

**Development of water cooled solid breeding blanket (6)**

**R&Ds on functional materials for blanket**

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**Neutron Multiplier Material**
- Fabrication technology of Be pebble was established.
- Be-Ti alloys are to be selected as an advanced material.
  - High melting point
  - Low oxidation

1) Pebble Fabrication Development

2) Characterization of Be-Ti Alloys ($\text{Be}_{12}\text{Ti}$)

<table>
<thead>
<tr>
<th>Main Properties</th>
<th>Results</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility with SS</td>
<td>$&lt;$1/10 of Be</td>
<td>Good</td>
</tr>
<tr>
<td>Swelling</td>
<td>$&lt;$1/50 of Be</td>
<td>Good</td>
</tr>
<tr>
<td>Tritium inventory</td>
<td>Lower release temp.</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Smaller inventory</td>
<td></td>
</tr>
</tbody>
</table>

Steam reaction rate of $\text{Be}_{12}\text{Ti}$ is about $1/1000$ of that of beryllium metal.

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Heat Arc Motor

Motor

W electrode

Electrode

Grain size ($\mu$m)

He-7at%Ti pebbles

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Structural material: SS316LN

Heating Temp.: 600 °C

Steam reaction rate of $\text{Be}_{12}\text{Ti}$ is about $1/10$.

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Atomic-scale modeling of tritium behavior at The University of Tokyo

Radiation damage in Li$_2$O by MD
- displacement energy
- favorable direction
- Li/O defect ratio
- recovery process

Cascade by 100 eV-Li$^+$ on $<111>$

Interaction of tritium with charged-defects in Li$_2$O by DFT
- effect of “the charged”
- barrier for detrapping

Stability of H near the F centers

Comparison between tritium release and annihilation of radiation defects in Li$_2$TiO$_3$

Hot atom chemical behavior of tritium in Li$_2$TiO$_3$ at Shizuoka Univ. and Kyushu Univ.

Oxygen vacancies could act as tritium trapping sites.
Development of Breeding Blankets (10)

Development of liquid breeding blanket (1)

Flibe blanket related study

Liquid blankets: Flibe, liquid Li and LiPb

Universities and NIFS

Advanced Options in Japan

Flibe blanket related study under JUPITER-II project at INL and UCLA

Purification
Material compatibility
Tritium Chemistry
MHD effect
Tritium permeation
REDOX control with Be

Experimental results on Redox control of Flibe with dipping Be.

Be metal can be applicable for the REDOX agent.

Updated high power magnet B.O.B. for heat transfer and flow filed measurement of Flibe simulant

Measured heat transfer coefficient by using Fli-Hy loop
Development of Breeding Blankets (11)
Development of liquid breeding blanket (2)
Li/ V blanket study

Li/V blanket related study
Key Research Topics
Material development
V-4Cr-4Ti : structural materials
Er$_2$O$_3$ and oxide ceramics : MHD insulator coating
Tritium recovery from lithium

![Images of plates, sheets, wires, and rods, thin pipes, creep tubes, W coating by plasma spraying, Laser weld joint.]

PVD coatings of Er$_2$O$_3$ on V-4Cr-4Ti were stable in liquid Li at 500-700°C for 1000 hrs

In-situ Er$_2$O$_3$ coating on V-4Cr-4Ti were shown to be a viable method for MHD coating for Li/V blanket

Products from high purity V-4Cr-Ti ingot (NIFS-HEAT-2)
LiPb blanket related study
: LiPb breeder, dual coolant concept (He coolant+LiPb heat transfer) with SiC insert for electrical and heat insulation to flow at higher temp.

Recent Progress: fabrication technique, high mechanical strength/toughness, high temperature performance and radiation effect under JUPITER-II activities

LiPb loop was installed and started operation under a collaboration with JAERI.

Major parameters:
- LiPb inventory : 6 liter
- flow rate : 0 – 5 liter /min
- temperature : 250 – 400 degree C

MHD and compatibility studies being performed.

The compatibility of SiC with LiPb is one of the remained feasibility concern. to be tested after modification for high temperature section.
Japan is investigating all fields of FNT for ITER and DEMO.
R&Ds on other FNT Issues (1)

PMI study under collaboration with Universities and JAERI

PMI and PFM studies have started under the joint research between Japanese universities and JAERI

Hydrogen isotopes (H/D/T) retention and erosion/deposition profiles were analyzed by various unique techniques (SIMS, TDS, IP, SEM).

Depth profiles of H and D observed by SIMS

H and D retention profiles in the divertor region well correlated with the carbon deposition profiles

The retained amount in the deposited layers, however, was very small (below 0.03 in (H+D)/C) compared to JET and other low temperature operational device.

Amount of retained hydrogen vs. thickness of re-deposition layer by TDS.
R&Ds on other FNT Issues (2)

Development of the divertor for ITER and DEMO

Advanced bonding technology for the ITER divertor has successfully been developed. Divertor mockups with "tungsten-pin" armor were developed by hot-pressing method.

Basic R&D's for the DEMO divertor have widely been performed in JAERI under collaboration with Japanese Universities.
- Critical heat flux (CHF) test of a high performance cooling tube, "screw tube"
- Thermal fatigue test of a divertor mockup with F82H screw tube
- Direct bonding test of tungsten armor and F82H heat sink by diffusion bonding
- Ion irradiation test of various tungsten armor
R&D on other FNT Issues (3)
Fuel processing System

R&D for fuel processing system
• Demonstration of a simulated integration system of main fuel cycle and blanket tritium recovery system
• R&D for ceramic proton conductor as an advanced blanket tritium recovery system
• Confirmation of durability of electrolysis cell in water detritiation system by $\gamma$ ray irradiation (530 kGy, ITER design value) and tensile tests
## R&Ds on other FNT Issues (4)

**Tritium Processing under developing at NIFS**

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Methods</th>
<th>Test Apparatus and Performance</th>
</tr>
</thead>
</table>
| Recovery of tritium from exhaust gas as pure hydrogen gas | Steam electrolyzer using proton conductor | • **Conductor:**  
\[ \text{CaZr}_{0.9}\text{In}_{0.1}\text{O}_{3-\alpha} \]  
one end closed tube  
(15\(\Phi\)x500Lmm;TYK)  
• **Hydrogen pumping rate:**  
1ml/min in air at 800°C  
• **Collaboration:**  
with TYK Co.Ltd. |
| Recovery of tritium from exhaust gas as tritiated water | Dehumidifier using hollow-fiber membrane | • **Membrane:**  
commercially available ones  
(UM-C10, et al.; UBE)  
• **Feed air flow rate:**  
100 NL/min  
• **Achieved dew point:**  
keep less than -70°C  
• **Collaboration:**  
with Shizuoka Univ. |
R&D on other FNT Issues (5)
Safety (1)

JAERI

R&Ds for ITER Safety Design
CATS : Caisson Assembly for Tritium Safety Study
  Tritium behavior under postulated accidents
ICE : Ingress-of-Coolant Event test facility
  Ensure and demonstrate adequacy of ITER safety design approach
Tritium Accountancy
Decontamination of Tritium

Universities, NIRS and JAERI

Fundamental and System Simulation Studies
  Tritium confinement
  Tritium-material interaction
  Environmental behavior
  Biological effect
To obtain data required for assurance of the ITER safety, a new caisson (12 m$^3$) has been built in the Tritium Process Laboratory and tritium release experiments have been carried out since December 1998.

Typical tritium removal behavior from tritium contaminated stainless steel wall in the dry air atmosphere under the conditions of detritiation flow rate of 36 m$^3$/h.
To demonstrate that the ITER safety design approach and design parameters for the ICE (Ingress-of-Coolant Event) are adequate, an integrated ICE test facility was constructed in December, 1999.

The system simulating ITER pressure suppression system →
Scaling factor: \( \sim 1/1600 \)
(the facility / ITER-FEAT)
Plasma chamber, Vacuum vessel, Simulated divertor, Relief pipe and Suppression tank

From the experimental results it was found quantitatively that the ITER pressure suppression system is very effective to reduce the pressurization due to the ICE event. Furthermore, it was confirmed that the analytical results of the TRAC-PF1 code can simulate the experimental results with high accuracy.
Permeation of heavy water vapor through cement paste
M. Nishikawa, et. al (Kyushu Univ.)

The diffusivity of water through the cement paste can be quantified from the curve using the adsorption isotherm. Then, the isotope exchange capacity and the rate of isotope exchange reaction are quantified. It is also confirmed that the estimated values using adsorption isotherm, diffusivity, isotope exchange capacity and rate of isotope exchange reaction obtained in this study give good agreement with results in the tritium penetration experiment into the column of cement paste.

Volume reduction of waste water by CECE process
T. Sugiyama, et. al (NIFS)

A pressure-reducing method was applied to the water-hydrogen chemical exchange in order to enhance the equilibrium separation factor. Hydrogen-deuterium isotope separation was performed using a trickle-bed chemical exchange column. The Kogel catalyst consists of 0.8 w-% Pt deposited on styrene-divinylbenzene copolymer. It confirmed that the separation factors under reduced pressure are larger than under atmospheric pressure. The HETP (Height Equivalent to a Theoretical Plate) values were distributed in the range of 6 to 15 cm.
The hydrogen isotope behavior in typical plasma facing materials have been studied at The University of Tokyo and Shizuoka University. The correlation between chemical state of materials and hydrogen isotope desorption process was discussed.

Deuterium desorption stages consists of two processes: Si-D and C-D bonds

Activation energy for Deuterium desorption from B-D-B (1.11eV) and B-D (2.17eV)
Effect of exposure of pregnant mouse to tritiated water or 137Cs-γ-rays on androgen receptor mRNA expression in male offspring epididymis

Pregnant mice were orally administered HTO (10.9 kBq/g BW) or exposed to 137Cs-γ-rays (0.3 Gy/h). Effects of radiation exposure on their male offspring were determined and the results indicated that no significant effects were observed on both items.

Translocation kinetics of atmospheric and soil D₂O (substitute for HTO) in tangerine

Uptake and loss kinetic parameters of D₂O in fruit of tangerine and translocation indexes at harvest were obtained in daytime and nighttime D₂O release experiments. The average translocation indexes (TLIa and TLIp) of deuterium as organically bound deuterium (OBD) in edible part of tangerine were 0.08% and 0.15% in daytime releases and 0.07% and 0.35% in nighttime ones. It was found that TLIa and TLIp in edible part of tangerine were 0.10-0.13% and 0.41-0.52%, respectively.

Availability of tritium gas oxidizing bacteria for tritium elimination system

In order to eliminate atmospheric tritium gas (HT) released from tritium handling apparatus, we intended to use HT oxidizing ability (enzyme hydrogenase) of the isolated bacterial strains from surface soils as a bioreactor. The bioreactors were made of bacterial cells grown on agar medium on cartridge filter and stored in a refrigerator until use. When HT contaminating air from the CATS in TPL/JAERI was introduced into the biological detritiation system, in which three bioreactors, each surface area of 216 cm² covered with strongly grown cells, 86% of HT in air was removed as tritiated water in these bioreactors at a flow rate of 100 ml/min for 2 hours.
Conceptual design of KOYO-Fast based on the fast ignition concept has been developed at ILE, Osaka University with collaboration of IFE forum.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Electric power with 4 modules</td>
<td>1200 MWe (300 MWe x 4)</td>
</tr>
<tr>
<td>Target gain</td>
<td>170</td>
</tr>
<tr>
<td>Fusion yield</td>
<td>200MJ/pulse</td>
</tr>
<tr>
<td>Lasers</td>
<td>1.1 MJ from 32 beams for compression and 100kJ for ignition operated at 16Hz</td>
</tr>
<tr>
<td>Laser material</td>
<td>Yb:YAG ceramic cooled to 150-220K</td>
</tr>
<tr>
<td>Laser efficiency</td>
<td>9.5% for compression laser and 3.5% for ignition laser</td>
</tr>
<tr>
<td>Thermal output</td>
<td>800 MWth</td>
</tr>
<tr>
<td>Blanket gain</td>
<td>1.13</td>
</tr>
<tr>
<td>Total thermal output of plant</td>
<td>3616 MWth (904 MWth x 4)</td>
</tr>
<tr>
<td>Electricity to thermal efficiency</td>
<td>42 % LiPb Temperature 500 C)</td>
</tr>
</tbody>
</table>
Two step strategy for the Demo-CREST Design studied by CRIEPI

1. to demonstrate electric power generation as soon as possible in a plant scale, with moderate plasma performance which will be achieved in the early stage of the ITER operation, and with foreseeable technologies and materials (Demonstration Phase)

2. to show a possibility of an economical competitiveness with advanced plasma performance and high performance blanket systems, by means of replacing breeding blanket from the basic one to the advanced one (Development Phase)

Table: Electric power and technology advancement in Development scenario by CRIEPI
JAERI conceives a compact DEMO reactor featuring
1. Down-sized center solenoid,
2. Slender TF coil system with a reduced stored energy (25 GJ),
3. Low aspect ratio (A ~ 2.6), and
4. Light, compared with conventional tokamak reactor designs

\[ R_p = 5.5 \text{ m, } a_p = 2.1 \text{m} \]
\[ B_T = 6 \text{ T, } I_p = 16.7 \text{ MA, } P_{\text{fus}} = 3 \text{ GW} \]
Based on the main advantage of current-less plasma, two sets of optimization have been studied at NIFS:

1. **to expand the blanket space by adjustment of the coil pitch parameter** $\gamma$ **of the continuous helical winding**, while reducing the magnetic hoop force to open wide maintenance ports,

2. **to solve the replacement difficulty by proposing a long-life blanket concept** STB (Spectral-shifter and Tritium breeder Blanket) using carbon tiles to soften the neutron energy spectrum on the self-cooled Flibe-RAF blanket.

Replacement-free blanket (first wall < 100dpa / 30y)
Summary

- Japanese fusion program clearly encompass the energy development through ITER and beyond.

- Construction and operation of ITER in a timely manner is essential with a view to participating into energy supply system in the middle of 21st century.

- Japan has a strong intention to contribute in FNT to the world fusion research program led by the construction of ITER, as well as IFMIF and other projects.

- R&Ds on Fusion Nuclear Technology have been conducted on all fields of FNT in Japan by JAERI, universities and research institutes, and in collaboration with international partners.

- Further involvement of domestic industries in the R&Ds on FNT is also deemed important in Japan.

- Continuous effort to maintain and increase the number of talented researchers for academia and industries is identified as an important issue and we are strongly making an effort to maintain human resource for fusion community.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>ISFNT-1 was organized.</td>
</tr>
<tr>
<td>1988</td>
<td>ISFNT-4 was organized.</td>
</tr>
<tr>
<td>1997</td>
<td>ISFNT-7 was organized.</td>
</tr>
<tr>
<td>2005</td>
<td>FNT R&amp;Ds were growing.</td>
</tr>
<tr>
<td></td>
<td>Future</td>
</tr>
</tbody>
</table>

FNT R&Ds toward Energy Production!

FNT in Japan was organized.

named “FNT”

matchmaker

named “ITER” and “DEMO”
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