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O-II-5.1
Development of Solid Breeder Blanket at JAERI

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Major Steps of Blanket Development in Japan

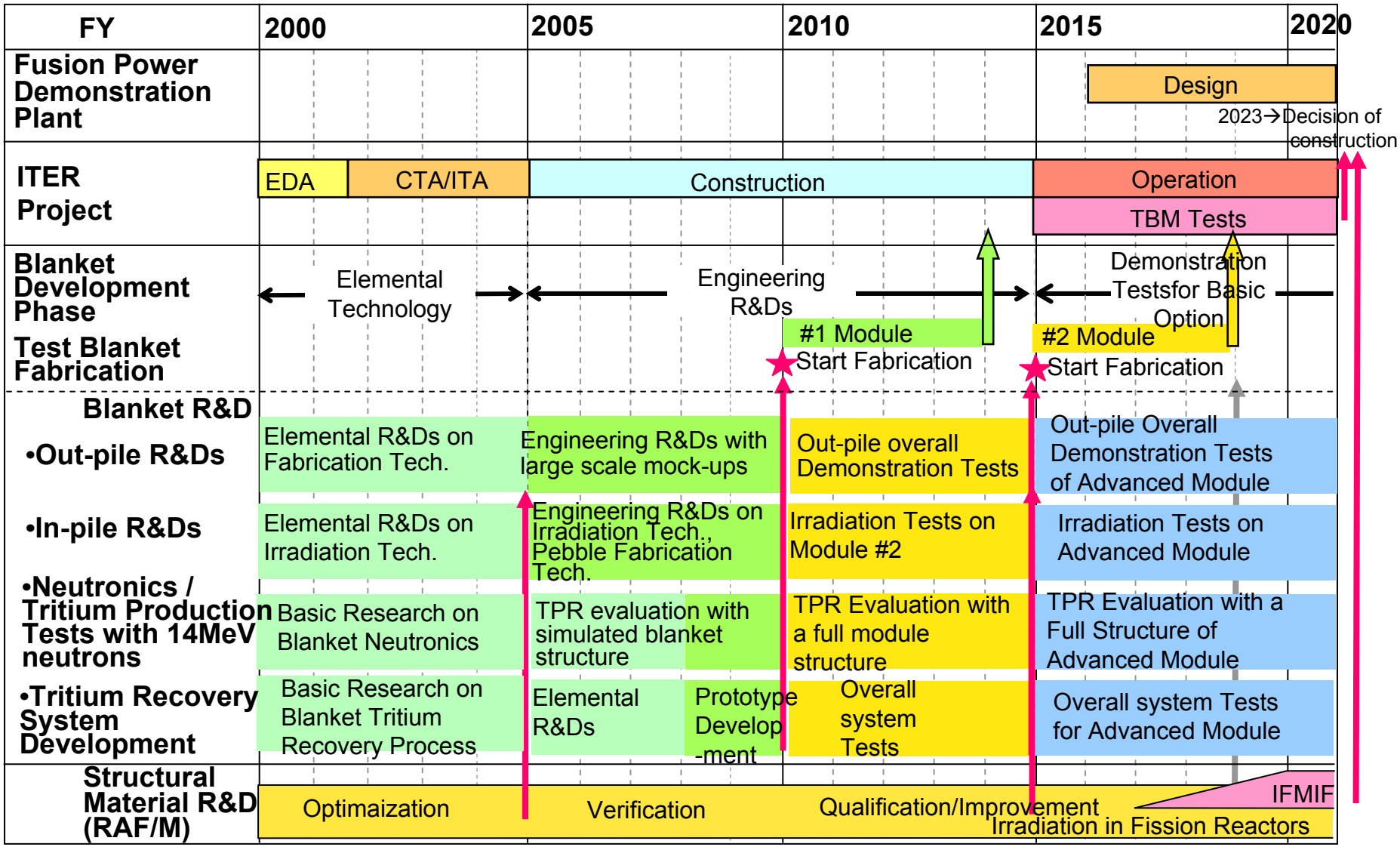
(1) Stepwise R&D program is being performed (Elemental Technology Development and Engineering R&D), for ITER blanket module testing.

- Out-pile R&D
- In-pile R&D
- Neutronics / Tritium Production Tests with 14 MeV Neutron
- Tritium Recovery System Development

(2) Milestones to the fusion power demonstration plant are

- qualification of blanket function and integrity by **ITER blanket module testing**, and
- material irradiation data by International Fusion Material Irradiation Facility (**IFMIF**).

Time Schedule of Blanket Development in JAERI



Organization of Blanket Development in JAERI

Fusion Reactor Design
Reactor System Lab.

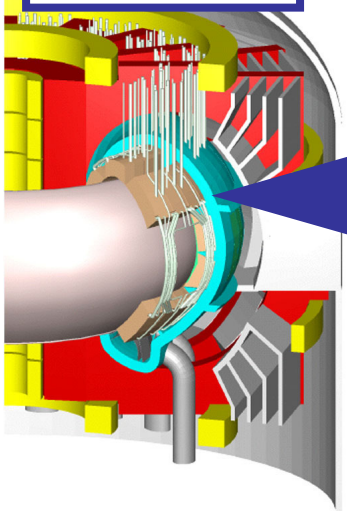
Out-pile R&D, Integration
- Module fabrication technology
- Thermo-mechanical,
- Thermal hydraulic research

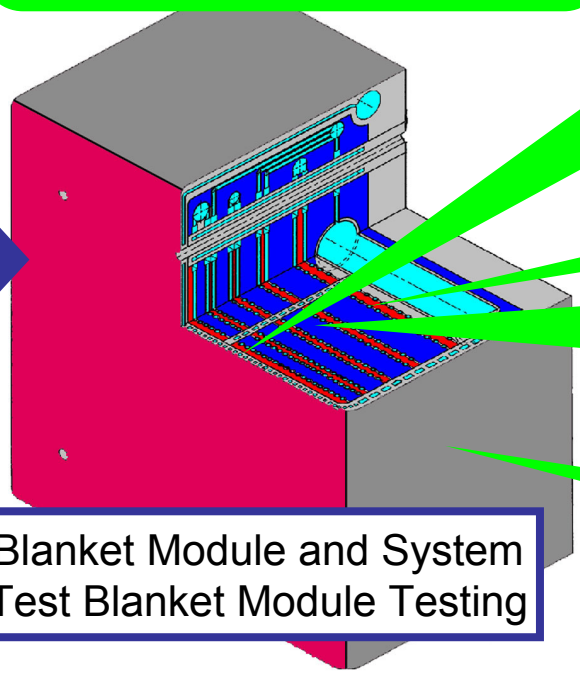
Blanket Engineering Lab.

In-pile R&D
- Breeder/multiplier development,
- Irradiation tests, • Irr. Tech.

Blanket Irradiation Lab.

DEMO2001





Blanket Module and System
Test Blanket Module Testing

Tritium Recovery System Development
- Process and system develop.

Tritium Engineering Lab.

Neutronics / Tritium Production Tests with 14MeV neutrons
- Neutronics peformance in mockup

Fusion Neutronics Lab.

Material Development

Office of Fusion Mater. Res. Promotion, Radiation Effects and Analyses Group

Cooperation and Collaboration
Universities (Basic Research), Industries (Fabrication Technology, System Engineering)
International Collaboration (IAEA, IEA, Bilateral)

Achievements of Elemental Technology Development

Out-pile R&D

- Fabrication of blanket box mockup, high heat flux tests of first wall mockup, and optimization of HIP joining process was completed.
- Compound data of thermal and mechanical design database was clarified for design of breeder / multiplier pebble bed structure.

In-pile R&D

- Basic fabrication technologies of Li_2TiO_3 and Be pebbles are established. Development of advanced pebbles showed steady progress.
- Irradiation tests of the Li_2TiO_3 pebble beds have shown feasible performance in simulated pulse operation of TBM in JMTR based on developed irradiation technologies.

Netronics / Tritium Production Tests by 14 MeV Neutron Source

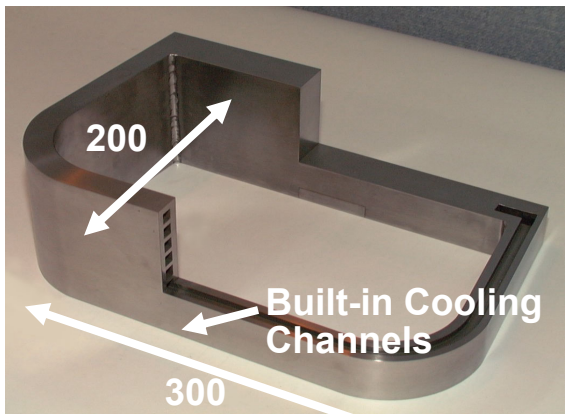
- Neutronics performance and Tritium Production Rate (TPR) was evaluated using 14 MeV neutrons with high accuracy, about 10% by simple mockups.

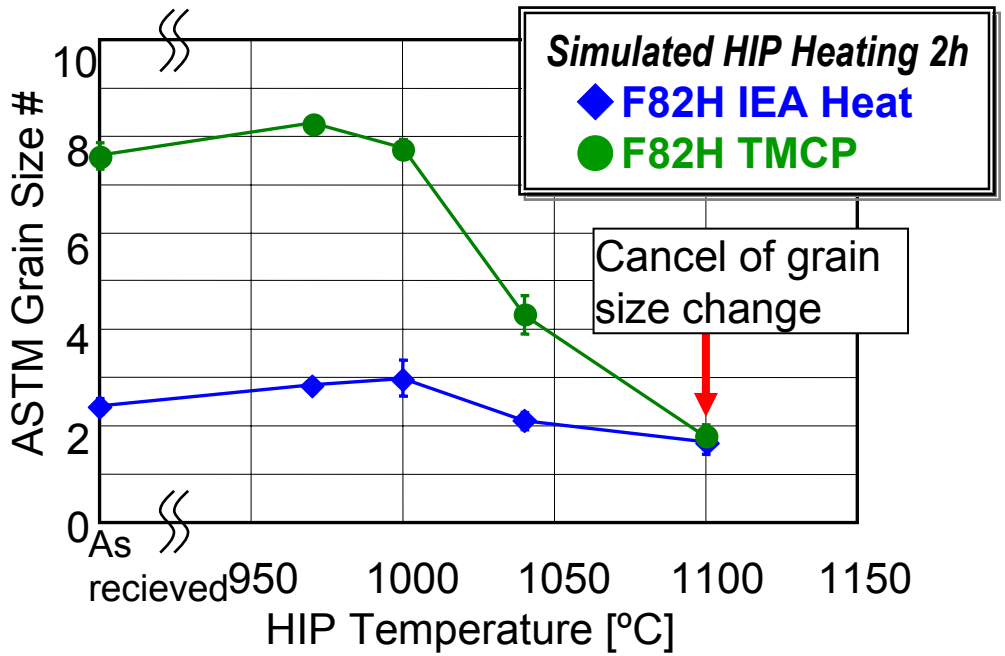
Tritium Recovery System Development

- Cryogenic Molecular Sieve Bed (CMSB) system was demonstrated.
- Protonic conductor membrane was investigated for tritium recovery from purge gas.
- PSA method with synthetic zeolite packed bed was investigated for enrichment of tritiated coolant water.

Out-pile R&D -Blanket Module Fabrication Technology-

(1) Hot Isostatic Pressing (HIP) condition was pre-selected for FW mockup fabrication.
(2) HHF test of FW mockup showed the relevancy of the fabrication of structure by HIP.





Grain coarsening was suspected.
Improvement of fracture toughness was needed.
→ Optimization of HIP process

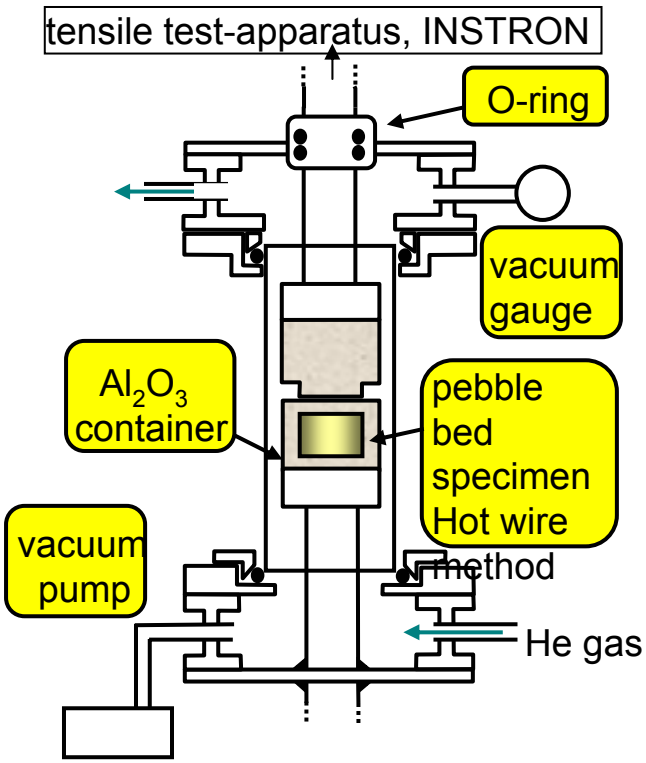
Heat treatment temperature to recover original grain size is clarified (>1100 ºC).

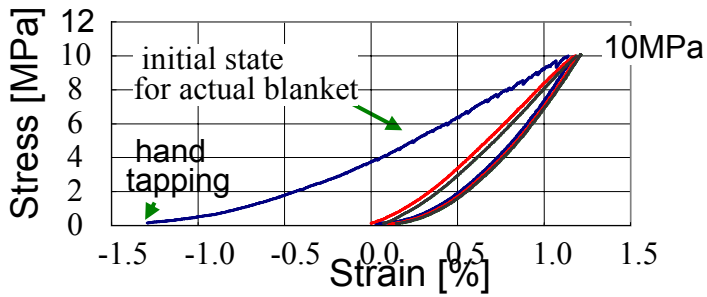
By heat treatment tests, HIP and post HIP heat treatment (PHHT) conditions have been optimized. → **HIP at 1150 ºC + PHHT at 930 ºC + Tempering**

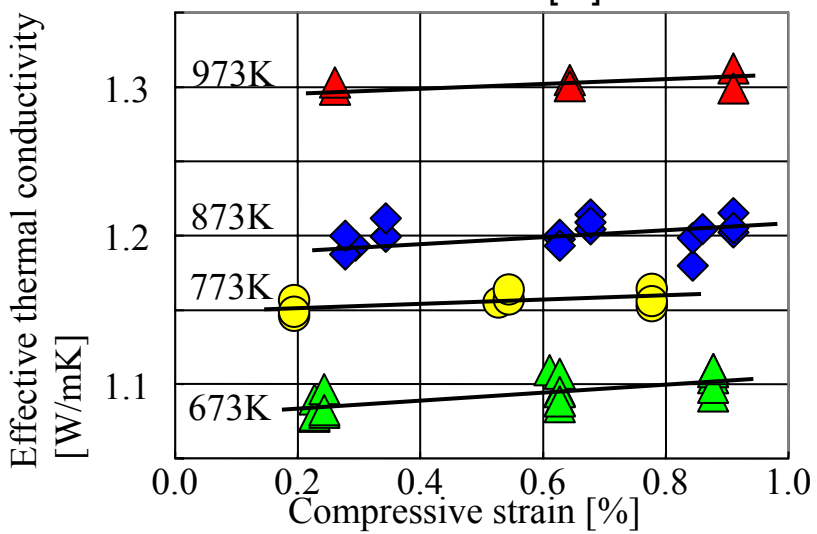
Out-pile R&D - Thermo-mechanical Properties -

(1) Baseline data of effective thermal conductivities of breeder and multiplier pebble beds were investigated, using hot wire method. Mechanical data was obtained under IEA collaboration.

→ Clarification of relationship between thermal and mechanical properties was needed for long term and cyclic operation of blanket modules.







Effective thermal conductivity of a compressed Li_2TiO_3 pebble bed

Increase of the effective thermal conductivity with a compressive load was confirmed in the temperature range from 400 to 700℃.

In-pile R&D - Development of Advanced Materials -

Tritium Breeder Material

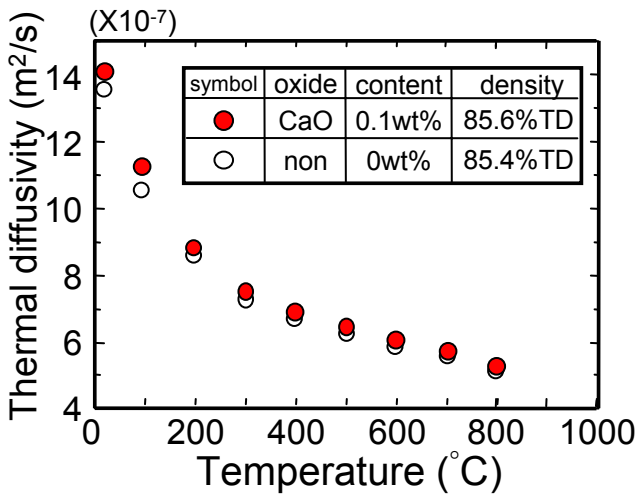
- Fabrication technology of Li_2TiO_3 was established.
- Oxide-doped Li_2TiO_3 was selected as an advanced material.

- Control of grain size - Chemical stability

1) Pebble Fabrication Development

- Success in fabrication of **^{6}Li-enriched** (30 and 95at%) Li_2TiO_3 pebbles and **TiO_2-doped Li_2TiO_3 pebbles** by indirect wet process.

2) Characterization

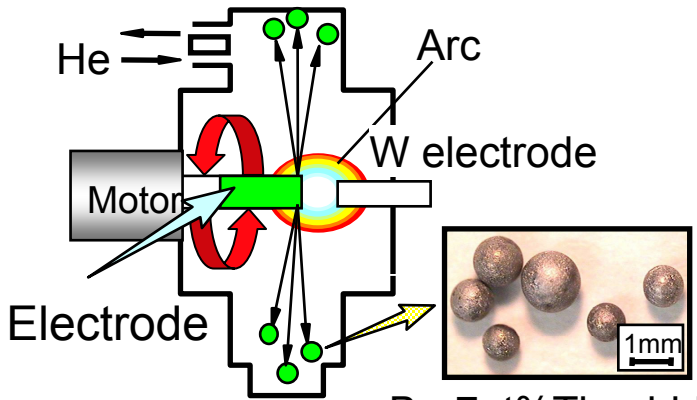


Neutron Multiplier Material

- Fabrication technology of Be pebble was established.
- Be-Ti alloys were selected as an advanced material.

- High melting point - Low oxidation

1) Pebble Fabrication Development



Be-7at%Ti pebbles

2) Characterization of Be-Ti Alloys ($Be_{12}Ti$)

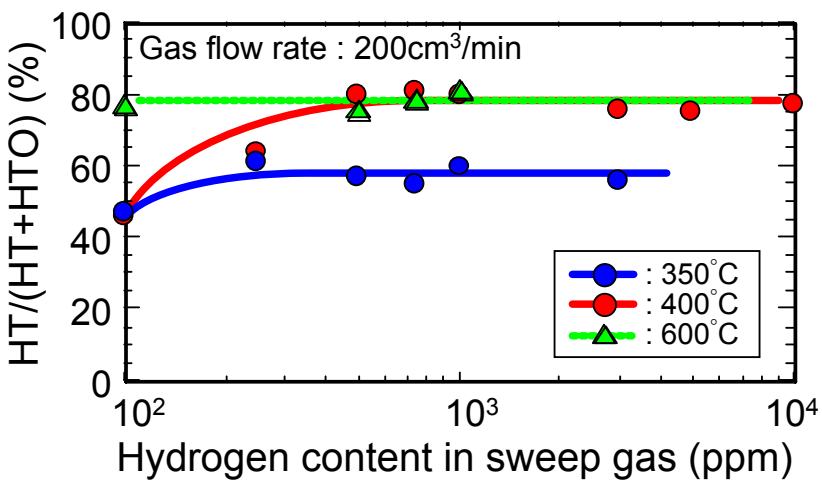
Main Properties	Results	Evaluation
Compatibility with	SS <1/10 of Be	Good
Swelling	<1/50 of Be	Good
Tritium inventory	Lower release temp. Smaller inventory	Good

Development of Irradiation Technology for In-pile Functional Tests

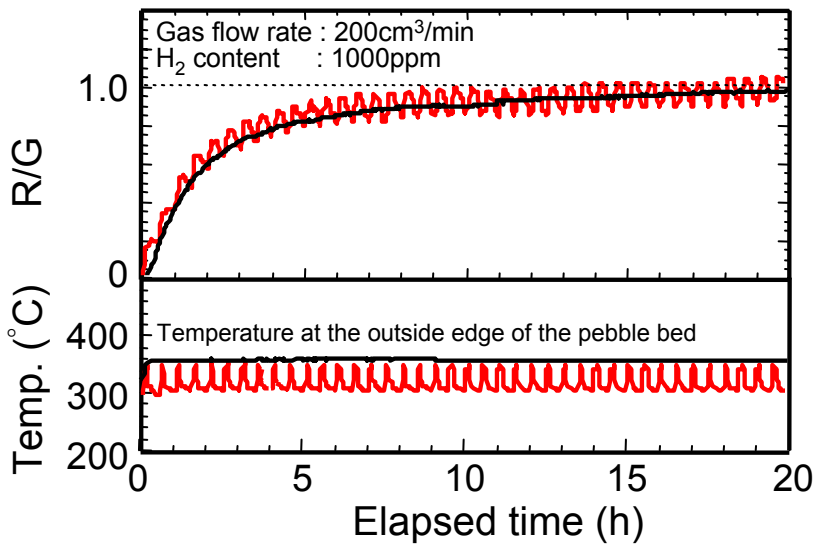
1) Pulse irradiation technique by changing the neutron flux with a neutron absorber window
2) Multi-paired thermocouples for measuring temperatures
3) Highly sensitive and responsive self-powered neutron detector (SPND)

Success in demonstration of tritium production and thermal performance in-pile test in JMTR, and clarification of tritium release characteristics.

1) Influence of hydrogen content in the sweep gas

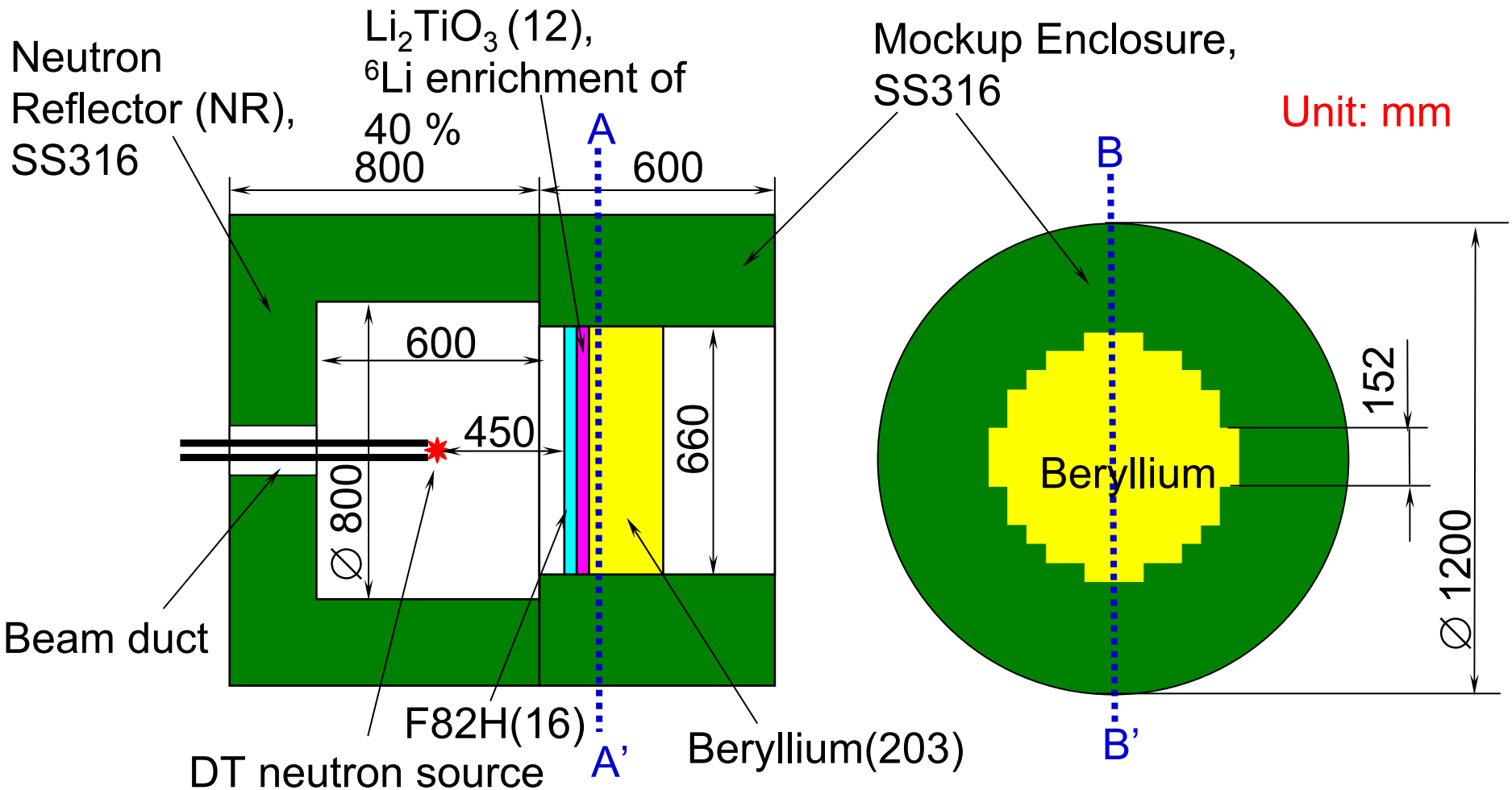


2) Tritium Recovery under Neutron Pulse Operation (ITER pulse operation)



Neutronics Experiments of DEMO Blanket (P-I-23)

Integral experiments have been performed using the partial mockup to verify the tritium productions by FNS.



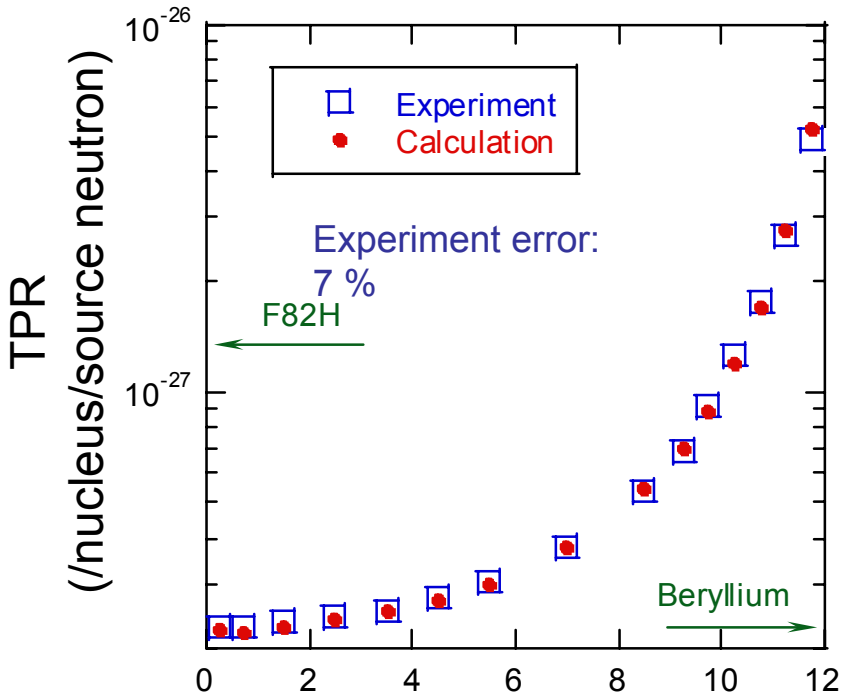
B-B' Cross Sectional View

A-A' Cross Sectional View

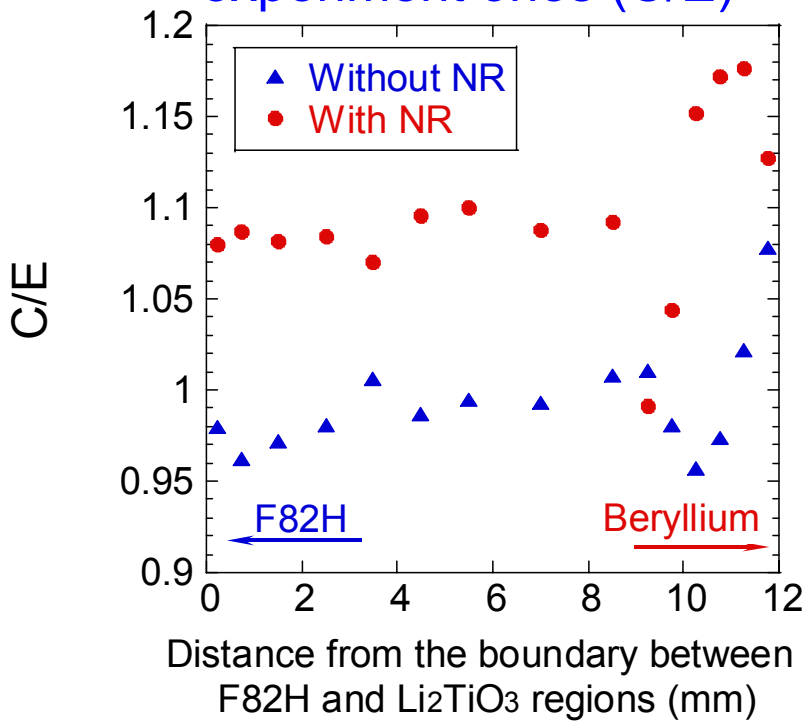
Neutronics Experiments of DEMO Blanket

Comparison of experimental data and numerical analyses using Monte Carlo code MCNP-4C and Japanese Evaluated Nuclear Data Library JENDL-3.2.

TPR without NR



Ratio of calculation results to experiment ones (C/E)

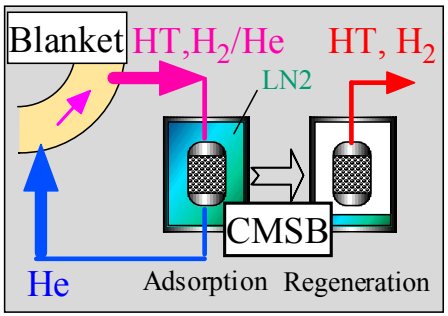


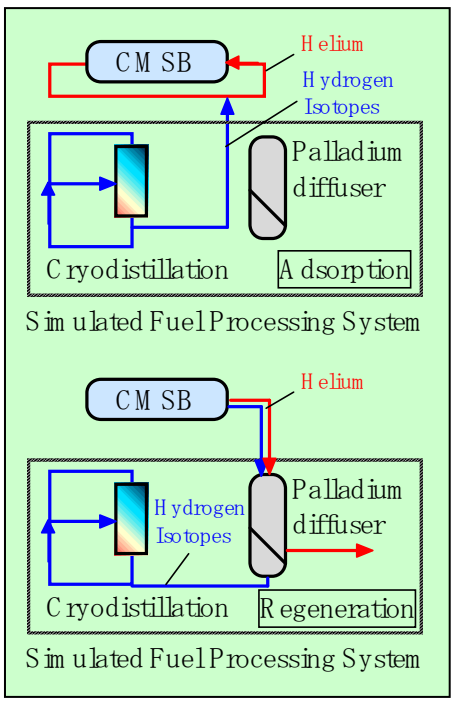
Distance from boundary between F82H and Li_2TiO_3 regions (mm)

C/Es of the local TPRs are 0.96 – 1.08 (av. 1.02) and 0.99 – 1.18 (av. 1.11) for the experiments without and with the neutron reflector, respectively.

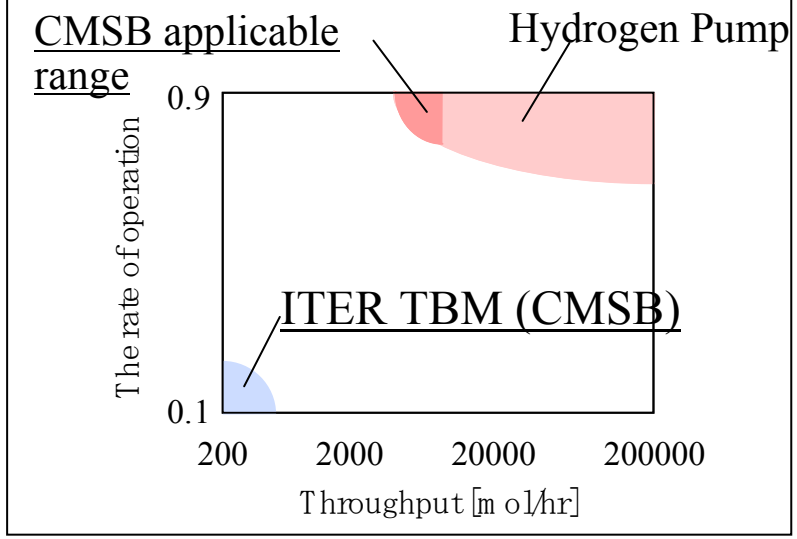
Tritium Recovery System Development (Breeder Purge Gas)

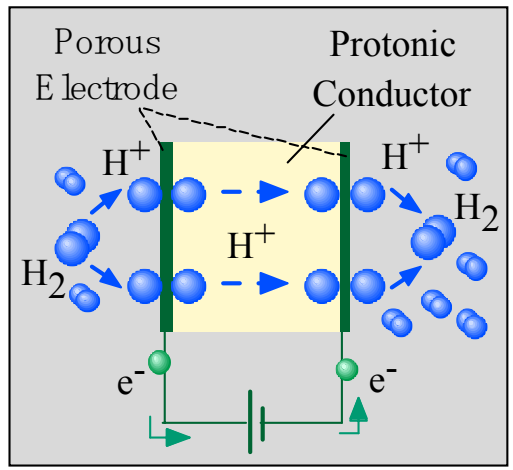
Cryogenic Molecular Sieve Bed

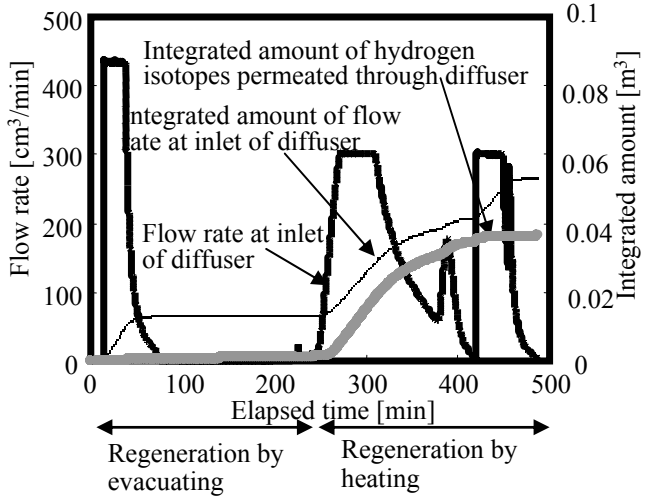




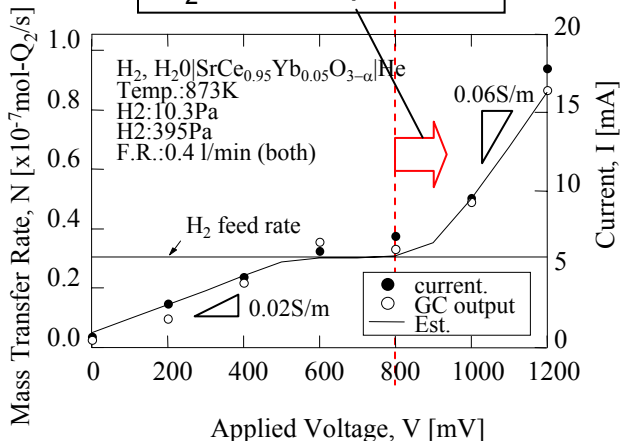
Electrochemical Hydrogen Pump







H_2 pumping via H_2O decomposition



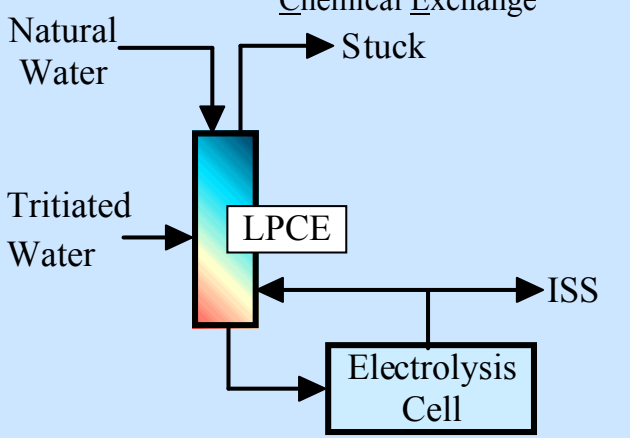
System integration of simulated fuel processing and CMSB system was demonstrated.

Ionic hydrogen transportation property was clarified.

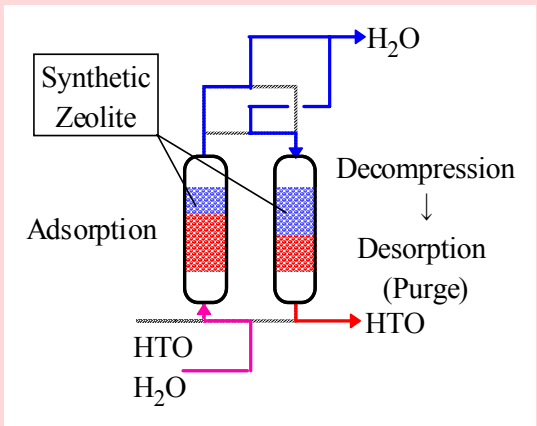
Tritium Recovery System Development (Blanket Coolant Water)

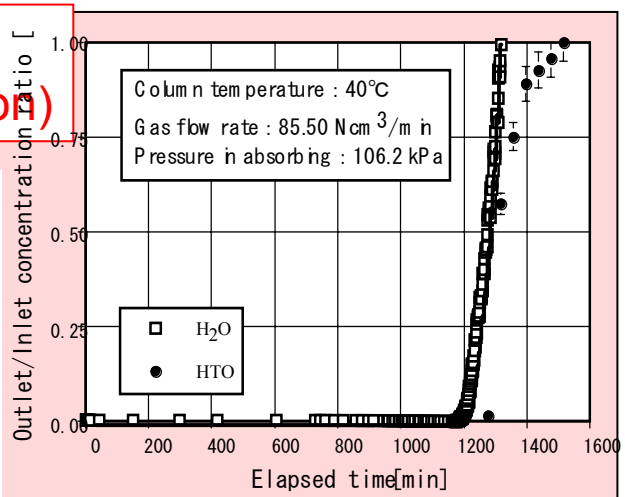
Applicable range of CECE (ITER-WDS)

Combined Electrolysis and Chemical Exchange

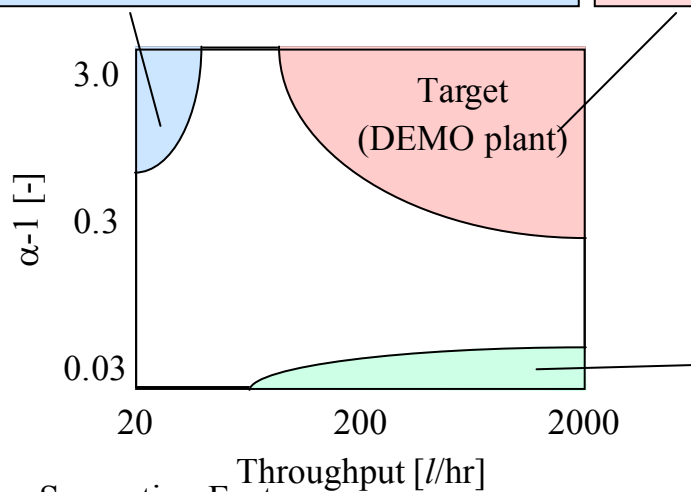


PSA column + CECE (pressure swing adsorption)





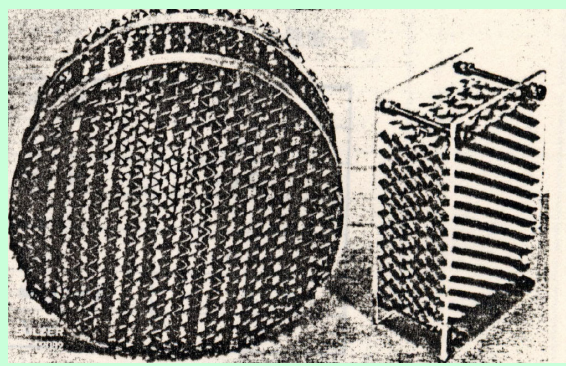
Breakthrough curves of HTO and H_2O.



α : Separation Factor

Column Height is inverse proportional to α-1 (≅lnα).

Applicable range of water distillation column (Old ITER design)



Packing Material of Water Distillation Column

Principle of HTO separation by PSA method was demonstrated.

Conclusions

(1) Organized long term blanket R&D is being performed, based on the program established by the Fusion Council of Japan.
(2) Essential elemental technologies of solid breeder blanket have been well investigated. Necessary data, technologies and experiences have been accumulated. Now, the development is stepping up to the Engineering R&D phase.
(3) In the Engineering R&D phase, real scale mockups will be fabricated and tested for the demonstration of the feasibility and the clarification of the manufacturing specifications of the ITER test blanket modules.

Related poster:
P-I-23 Neutronics experiments using small partial mockup of the ITER test blanket module with solid breeder, by Sato et al.