Accomplishment of DEMO R&D Activity of IFERC Project in BA activity

and

Strategy toward DEMO & Progress of conceptual design study on Japanese DEMO

Hiroyasu Tanigawa
Ryoji Hiwatari

National Institutes for Quantum and Radiological Science and Technology (QST)
JAPAN
Technical demands on DEMO Design and R&D activity

**Conceptual design of JA DEMO**

*Fusion Power* compatible with *divertor heat-handling* \( \Rightarrow P_f = 1.5 - 2.0 \) GW

*Device size* compatible with *operation flexibility including pulse operation* \( \Rightarrow R = 8m \) class

*Breeding Blanket system* consisted with the rational combination

\( \Rightarrow \) Water Cooled Ceramic Breeder for primary system and advanced option for DEMO-TBM

Need to establish basic strategy of safety assurance of fusion system

**Design challenges** to overcome weaknesses in water-cooled DEMO

- T permeation into the primary coolant in in-vessel components
- T management in the primary coolant loop
- Confinement concept for T release from the primary coolant loop in a pipe break accident.

**Technical challenges** on materials and technologies related to breeding blanket

- Structural material which fulfill the technical demands
- Neutron multiplier and T breeder compatible with water-cooled system
- Advanced material for functional structure application of dual-coolant liquid metal breed system (DEMO-TBM)
- T handling technologies which form the technical basis of safety and T breeding
Highlight: DEMO plant concept related to tritium handling in the primary coolant system is developed.

1. T permeation into coolant
   - Blanket pathways
   - Divertor pathway
   - T permeation into coolant was estimated to be as low as 5.7 gT/day = 2.5% of produced T

2. T extraction from coolant
   - T permeation 5.7 gT/day
   - 94 kg/h
   - WDS
   - Bypass
   - 5.7 gT/day T removal
   - Management of T concentration in the coolant is viable by applying an existing water detritiation system (WDS) of CANDU.

3. Confinement of T at LOCA
   - Combination of “cooling water vault” and “suppression pool” is effective to mitigate T environmental release due to a large scale ex-vessel LOCA.

Early public dose: as low as 1.8 mSv \ll 50 mSv of no evacuation limit
T permeation into water can be resolved in DEMO

- Tritium permeation was estimated for three pathways via: 1) blanket surface, 2) inside blanket, and 3) divertor surface.

- For the permeation of 5.7 gT/day, T concentration in the coolant can be kept at 1 TBq/kg or lower by applying an existing water detritiation system (WDS) of CANDU.

- Actually, the required water to be processed is 94 kg/h for DEMO, which is satisfied with the specifications WDS in Wolsong (Korea).

- Tritium permeation was estimated to be as low as 5.7 gT/day at most.

(K. Katayama et al, Estimation of Tritium Permeation Rate to Cooling Water in Fusion DEMO Condition, 4B-6, Tritium 2016, US)
A new concept of T confinement in ex-VV LOCA

- Ex-VV LOCA discharges the tritiated coolant (1TBq/kg) in the final confinement barrier.
- Installation of a Suppression Pool (SP) is proposed to mitigate the pressure increase in the Upper Tokamak Hall (UTH), constituting the final barrier.
- The SP can reduce the pressure in the UTH to less than 0.12 MPa.
- The resultant release of tritium from UTH can be drastically reduced.

The resultant early dose to the public can be reduced to 1.8mSv << *50mSv.
*(“no-evacuation” dose limit recommended by IAEA)
Requirement for the blanket system

Required function
• Shield the high energy fusion neutron
• Breed Tritium (TBR > 1.05)
• Convert neutron energy into heat

Expected performance
• Assure safety and reliability throughout the assumed service period under the assumed operation mode.
• Reduce radioactive level which is consistent with waste management and recycle strategy.
• Ensure maintenance and inspection service are feasible.

★ Materials & Tritium technology development for blanket system is expected to provide sound engineering bases for safety, reliability and feasibility of blanket designs.
The highlights of the accomplishment of DEMO R&D

Demonstration of RAFM steel F82H’s good reproducibility in DEMO scale production technologies.

Suppression of passivation behavior of SS304 by tritiated water, but not the case for SS316.

Pebble of super advanced tritium breeder LTZO20 $\text{Li}_{2+x}\text{TiO}_{3+y}$ with 20 wt.% $\text{Li}_2\text{ZrO}_3$

Be$_{12}$V single phase pebbles as advanced neutron multipliers

Chemical stability of pure SiC/SiC composite in high temperature liquid Pb-Li

SiC/SiC as Insulator (for liq. breeder)

RAFM as Structural material

Tritium

Breeder

Multiplier

LTZO20 pebbles

Good results of reactivity
Strategy toward DEMO beyond BA activity

**Blanket Technologies**

- **TRL** Technical Readiness Level

**RAFM Steel**

*Structural material*

**SiC/SiC**

*Flow channel insert for DEMO-TBM*

**Tritium**

**Breeder**

**Multiplier**

**To get ready for Fusion DEMO application.**

Demonstration and endorsement of these developed technologies in industrial level, under DT fusion in-vessel environment.

**Operation of ITER-TBM in DT phase**

- The important demonstration to prove its feasibility (But, <3dpa)

**An intense fusion neutron source**

*Relatively large volume, constant / high dose fusion n. irradiation facility*

- Verification of materials and blanket technologies under DEMO-like environment.

**Advanced Fusion Neutron Source**

Related facilities (Tritium Process, Radioactive, PIE)
Summary

Demo concept development

✓ Plant concept related to tritium handling in the primary coolant is developed.
  □ Tritium permeation into the coolant in the in-vessel components is evaluated to be \(5.7\text{gT/day}\).
  □ T management keeping \(1\text{TBq/kg}\) in the primary coolant is found to be possible using the existing tritium removal facility of CAMDU.
  □ Confinement concept of T release at ex-vessel LOCA is proposed using suppression pool system, resulting early dose to the public \(1.8\text{mSv}\).

Demo R&D activity

✓ Five R&D tasks on blanket technologies were conducted in the BA DEMO R&D activity, and the major accomplishments are as follow.
  □ Demonstrate RAFM steel, F82H, potential as the DEMO structural material
  □ Prove the stability of SiC/SiC composite for functional structure application
  □ Developed Beryllide (Be\(_{12}\)V) as the advanced neutron multiplier
  □ Developed Li-titanete/Li-Ziroconate ceramic as the advanced tritium breeder
  □ Tritium handling technologies.

Next step

✓ Need an intense fusion neutron source to demonstrate these technologies.