Unique Integrated Testing Facility (UNITY) for Fusion Power Generation

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1. Introduction

No test facility for fusion power generation systems exists → no demonstration of the feasibility of power generation by fusion.

- Engineering R&D for plant components (indispensable for the commercialization of fusion power generation) still in its infancy

No heat extraction and energy utilization from the breeding blanket have been demonstrated.

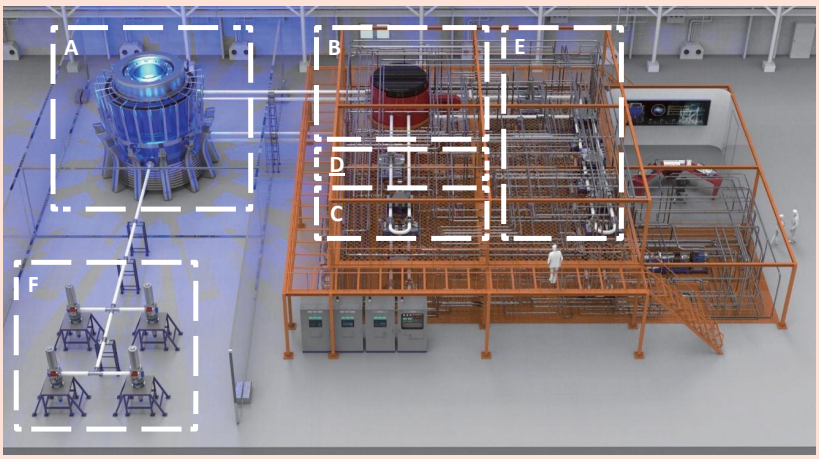
- Such tests are not planned for ITER and need to be demonstrated quickly for practical use

No high-temperature energy utilization system using liquid metal or molten salt has been demonstrated.

- A high temperature (1,000°C) energy cycle using liquid metal/molten salt must be demonstrated
- There are challenges inherent to fusion plants, such as tritium migration in the high-temperature cycle

Beyond lab-scale integrated power cycle R&D is needed before we can build a commercial fusion reactor!

2. Construction plan for UNITY



3. UNITY Project Timeline

Stage 1 (2022)
Demonstration of the lithium-lead loop
- Study and verification of materials and components required for a fusion plant

Stage 2 (2023)
Start of the blanket testing campaign
- Demonstration of advanced blanket performances in experiment + simulation

Stage 3 (2024)
Start of the power cycle demonstration
- Demonstration of energy conversion components through electricity generation

Stage 4 (2025)
Integrated divertor and gyrotron testing
- Demonstration and R&D of core Kyoto Fusioneering products for the fusion industry

4. Conclusion

- **UNITY will provide the integrated fusion plant technology at TRL>6 to be available for the first fusion reactors after 2026.**
- **UNITY can accommodate various plasma types (magnetic, inertial, innovative) for power conversion and fuel cycle.**
- **UNITY will be ready for collaboration and various business for commercial fusion for industrialization.**

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A. Blanket and Divertor Integrated Testing Section

Testing Capability for Multiple Blanket Types

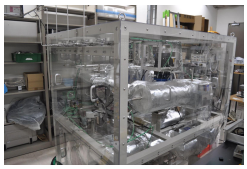
- Experimental capability **with multiple coolants** including LiPb, Li, FLiBe, and H_2O).

Testing in 4 T Magnetic Field

- Strong magnetic field with gradient to measure MHD effect in blanket module

Extraction of High-Temperature Coolant

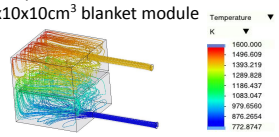
- External heating to simulate volumetric heating & temperature distribution of **up to 1,000°C**
- Vacuum insulation to minimize heat loss

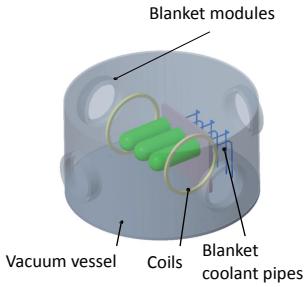


FLiBe loop

LiPb loop

Flow optimisation for 10x10x10cm³ blanket module





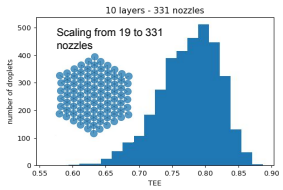
C. Fusion Fuel Cycle Demonstration Section

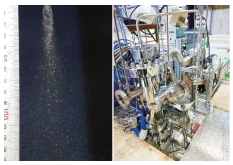
R&D and Demonstration of Tritium Recovery:

- UNITY will demonstrate **tritium recovery from the blanket for three primary coolants** (FLiBe, LiPb, and Li) at relevant scales
- Tritium/droplet interaction code development for scaling of new generation devices

Tritium Handling and Storage

- R&D and demonstration of tritium handlings, **including the pumps for tritiated gas**
- Assessment of detritiation and isotope separation technologies





Tritium extraction demonstration from LiPb Loop via Vacuum Sieve Tray [Okino 2019]

D. Tritium Pump Testing Section

Tritium Roughing Pump

- **High tritium compatibility**
  Oil-free, continuous operation is possible with high concentration of tritium
- **Handles air, helium, hydrogen, oxygen**
  Almost same performance with different gas species (D2, He, T2…)
- **Smaller pump train, no-metal bellows pump**
  Substitute for a combination of scroll pump and metal bellow pump
- KF received prototype and testing with H/D ongoing

Proton Conductor Pump (PCP)

- **Direct Internal Recycling (DIR)**
  Low tritium inventory, smaller detritiation facilities
- New prototype with Al2O3 tube manufactured for better vacuum, testing ongoing

New roughing pump design

PCP prototype

B. High-Temperature Heat Exchange and Extraction Testing Section

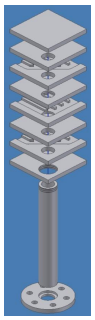
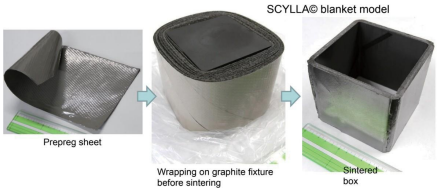


Plate heat exchanger design

Developing for >50% thermal efficiency

- **capable of performing heat exchange up to 1,000° C** in a simulated fusion plant environment
- **enables compatibility tests of liquid metal/molten salt with various materials**
- Measurement of tritium permeation for complex geometries
- R&D on advanced manufacturing methods for SiCf/SiC components based on the technology developed at Kyoto University



D. Energy Utilization Testing Section

UNITY will conduct the world's first power generation demonstration test at the end of 2024

- **Various power generation cycles from heat extraction from the blanket** (Brayton cycle, Rankine cycle) **under power plant conditions**
  - World's first demonstration of power generation from a blanket
  - This experiment will yield critical understandings of fusion power systems and key parameters required for designing a power plant
  - High-temp heat exchange and tritium permeation to the generation system should not be underestimated
- **UNITY will demonstrate alternative applications of high-grade heat, including hydrogen production**

E. Multipurpose Testing Section

For corrosion testing under flow conditions, etc.

F. Gyrotron Operation Section

KF Gyrotron already demonstrated 1 MW oscillation for each frequencies (28 GHz to 203 GHz)

Output Power	1 MW
Frequency	Selectable[a] from 28 GHz to 203 GHz [a] The frequency can be adjusted based on customer request
Pulse Width	CW operation
Efficiency	>50%, from input power to output RF
Mode Purity	>90%, from TE mode to HE11 mode
Conditioning	Shall be operated by KF
Lead Time	Approximately 20 months from order to delivery

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Digital Version of this Catalogue

KF Official Website