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International Symposium on Present Status and Future Perspective for Reducing Radioactive Wastes ~ Aiming for Zero-Release ~

# Hitachi's activity for transmutation system of long-lived radioactive waste

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# Contents

# 2. Hitachi's activity outline

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Cooperate on SFR/Fuel cycle national projects
Investigate an option based on BWR experiences

| Sodium-cooled MA burner | BWR TRU burner |
| --- | --- |
| Advancing SFR performance<br>Conducted as MEXT project | Advancing BWR features<br>Study on option for SFR |

| Flexible fuel cycle |
| --- |
| Adaptive to various fuel cycles, debris management<br>Conducted as MEXT project |

SFR: Sodium-cooled Fast Reactor
BWR: Boiling Water Reactor
MA: Minor Actinide
TRU: Transuranium element
MEXT: Ministry of Education, Culture, Sports, Science & Technology

# 3. MEXT Project for MA burner

Pursuing harmonization of efficient MA transmutation with enhanced safety characteristics

"Study on minor actinide transmutation using MONJU data"*

* This material includes 2013 results of the study entrusted to University of Fukui by MEXT.

**University of Fukui**
Management

- **Univ. Fukui/Kyoto/Osaka**
  Advanced analysis method
- **JAEA/Hitachi-GE**
  Advanced core design
- **JAEA**
  Related experimental data analysis, DB construction
- **Hitachi-GE**
  Transient, Accident analysis

# 4. Advanced homogeneous MA core

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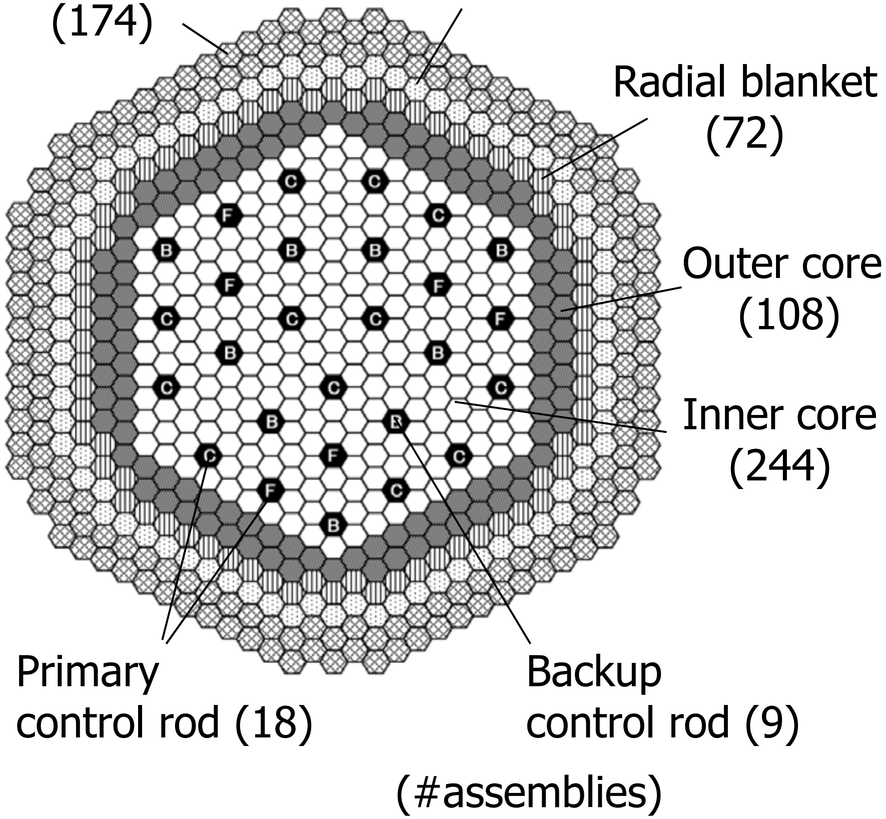
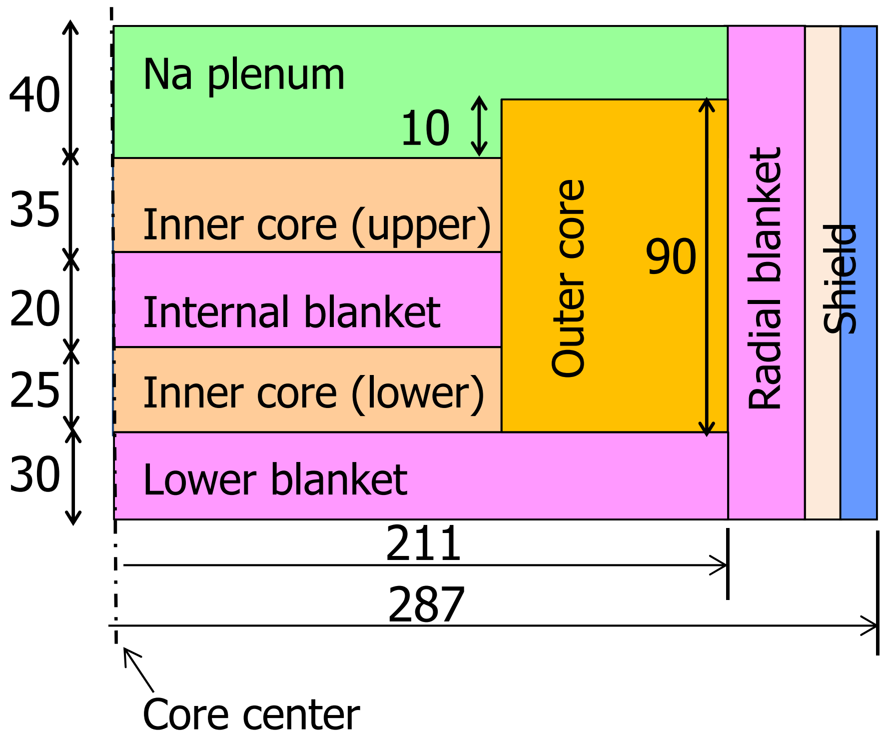
## Reduce absolute value of void reactivity by placing Na plenum* on the top of core

* K. Kawashima, K. Fujimura, et al., "Study of the Advanced Design for Axially Heterogeneous LMFBR Cores," Proc. of FR91




Horizontal configuration




Axial configuration (1/2 core)

# 5. Core specification and performance

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| | Item | Unit | Value |
|---|---|---|---|
| Specification | Output (electric/thermal) | MWe/MWt | 750/1,765 |
| | Operation cycle | month | 18.6 |
| | Number of batch (core/radial blanket) | - | 6/6 |
| | Core height (inner/outer) | cm | 60/90 |
| | Internal blanket height | cm | 20 |
| | Na plenum height (inner/outer) | cm | 40/30 |
| Performance | Pu enrichment, MA content (inner/outer)* | wt% | 27.4/24.8, 6.8/6.1 |
| | Burnup reactivity | %Δk/kk’ | 0.63 |
| | Breeding ratio | - | 1.14 |
| | Maximum liner heat generation rate | W/cm | 396 |
| | Discharged exposure (core/all) | GWd/t | 149.3/78.9 |
| | MA transmutation amount | kg/GWe/y | 103 |
| | MA transmutation rate | %/discharge | 36 |
| | Void reactivity (EOEC) | $ | 3.6 |
| | Doppler coefficient (EOEC) | Tdk/dT | $-5.0\times10^{-3}$ |

EOEC: End of equilibrium cycle

* Suppose TRU isotopes from LWR’s spent fuel

# 6. Safety analysis with effective void

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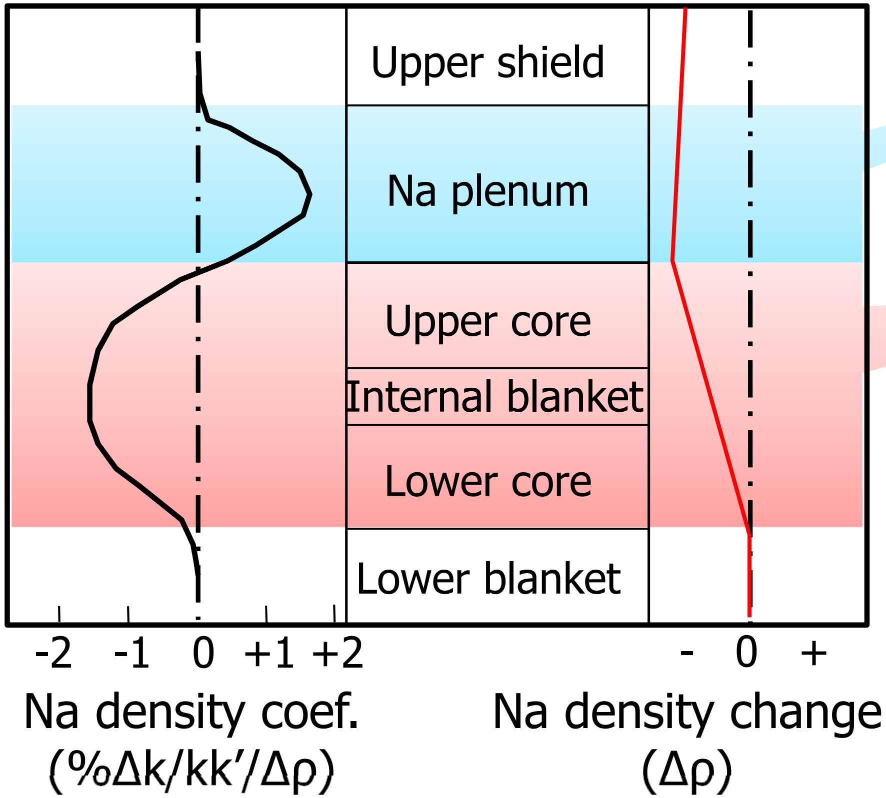
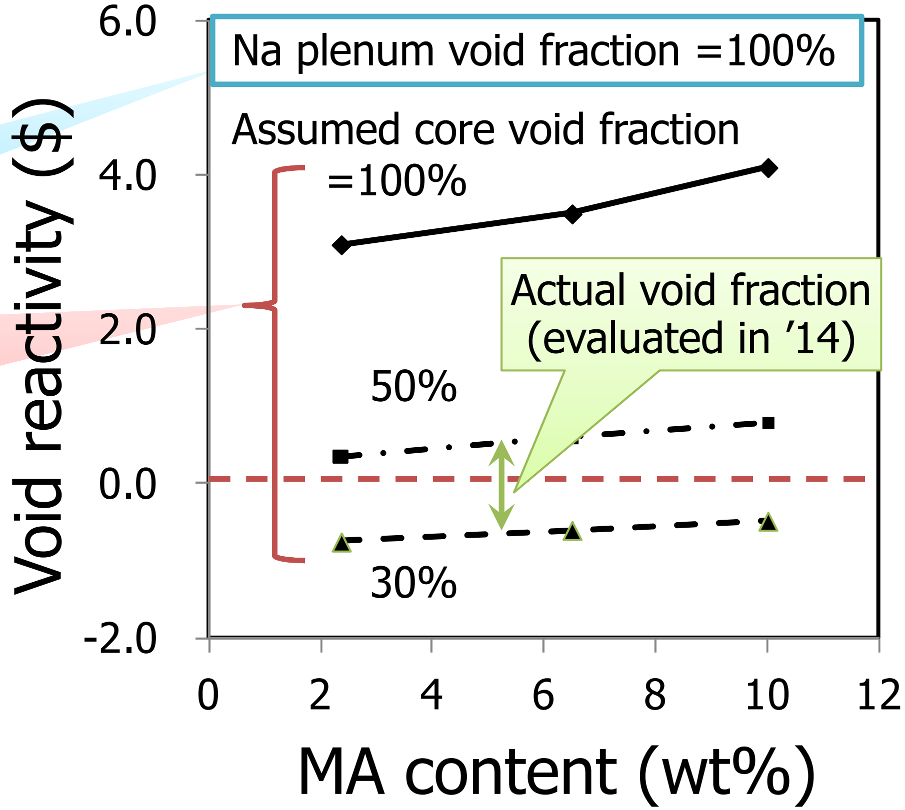
## Negative void reactivity under transient might slow event progress




Na density and reactivity coef. axial distribution

Void reactivity dependency on core void fraction

⇒Study to enhance MA transmutation and safety is in progress

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# 7. Hitachi's activity outline

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| Advancing SFR performance<br>Conducted as MEXT project | Advancing BWR features<br>Study on option for SFR |

| Flexible fuel cycle |
| --- |
| Adaptive to various fuel cycles, debris management<br>Conducted as MEXT project |

# 8. BWR feature for TRU burner

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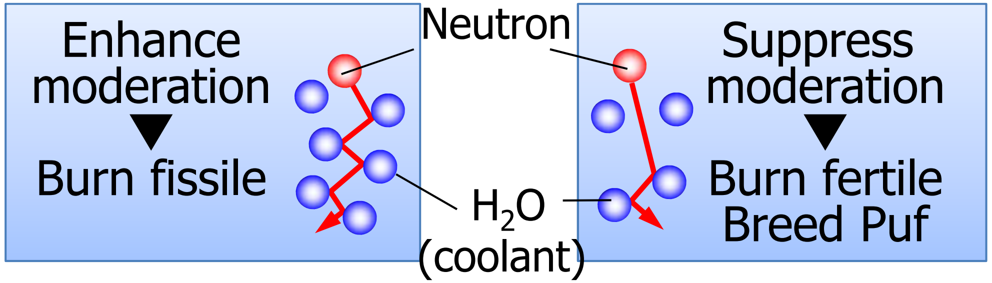
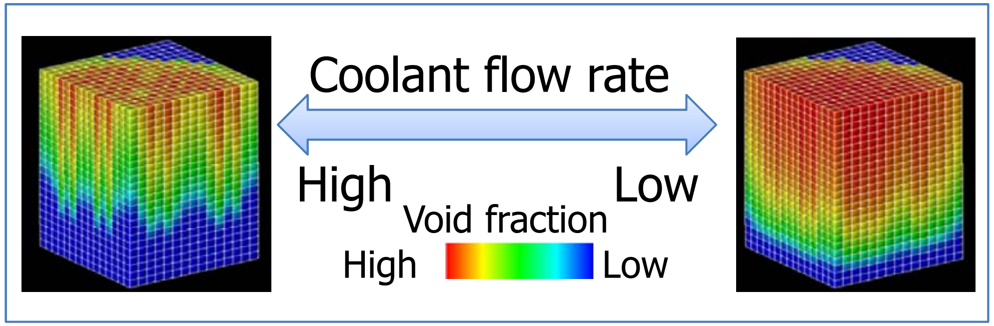
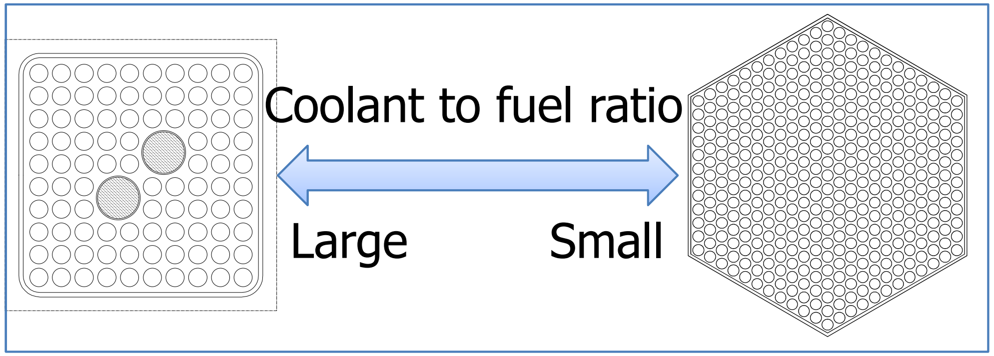
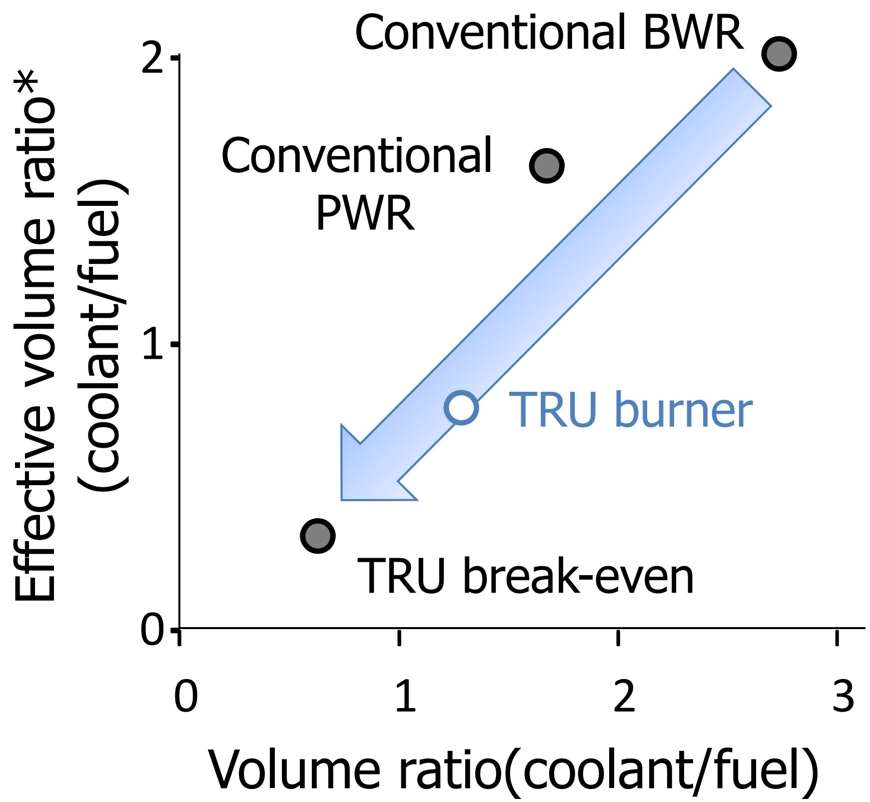
## Advance BWR's moderation controlling capability to burn not only fissile but also fertile




* Coolant void fraction is considered

# 9. RBWR concept

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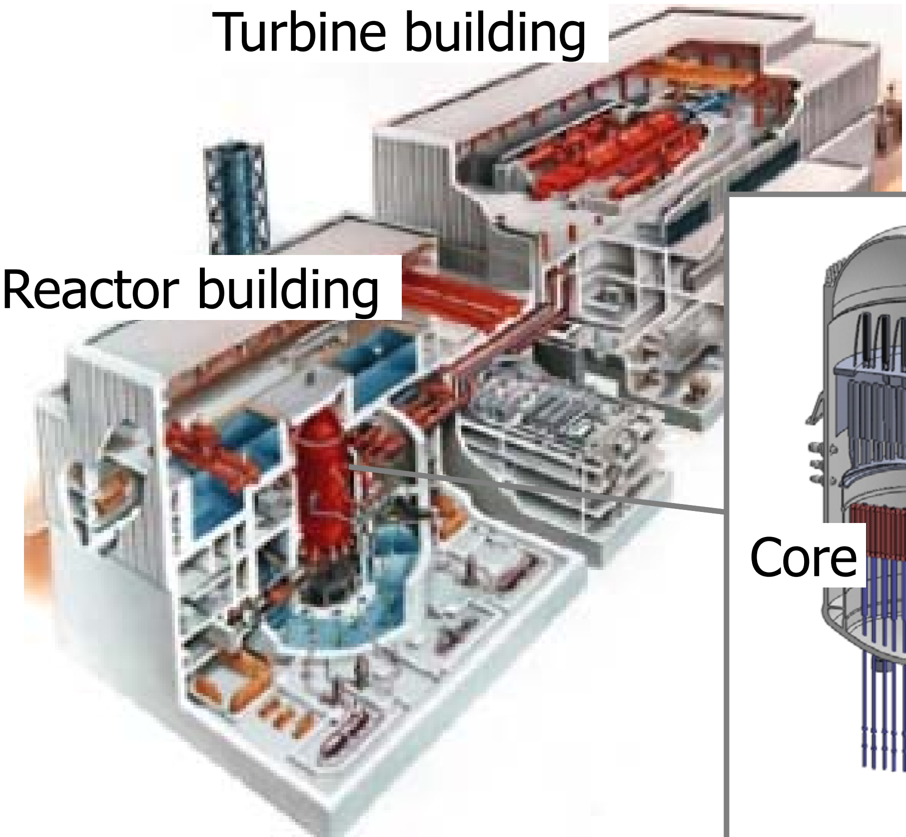
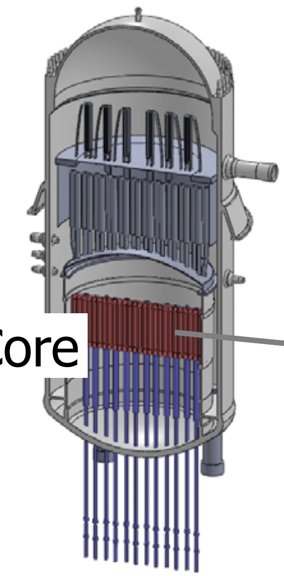
Reduced moderation core is optimized for TRU burning
Safety system, BOP, etc. are almost same as conventional BWR

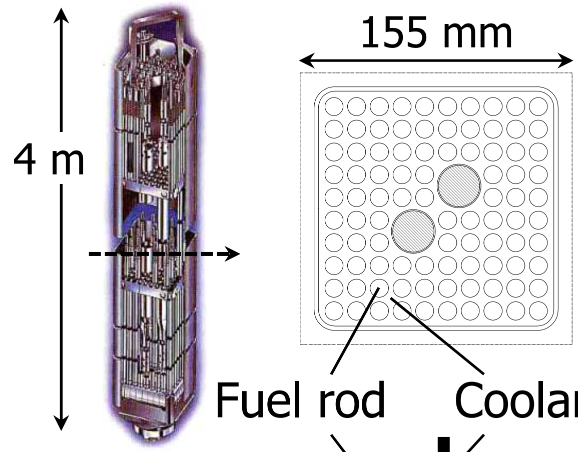



Plant cut-away view

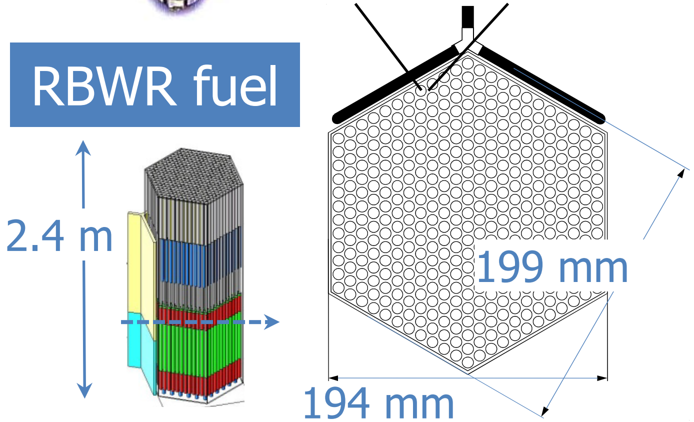



Pressure vessel

Conventional BWR fuel




RBWR fuel




RBWR: Resource-renewable BWR

# 10. Core configuration

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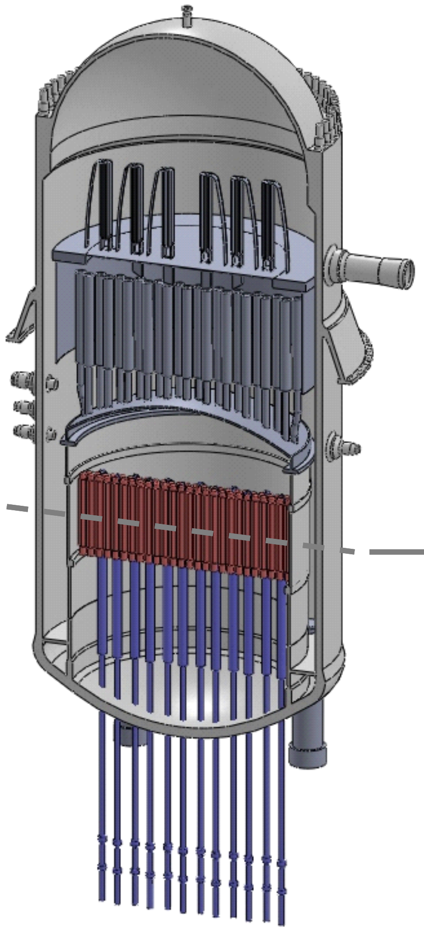
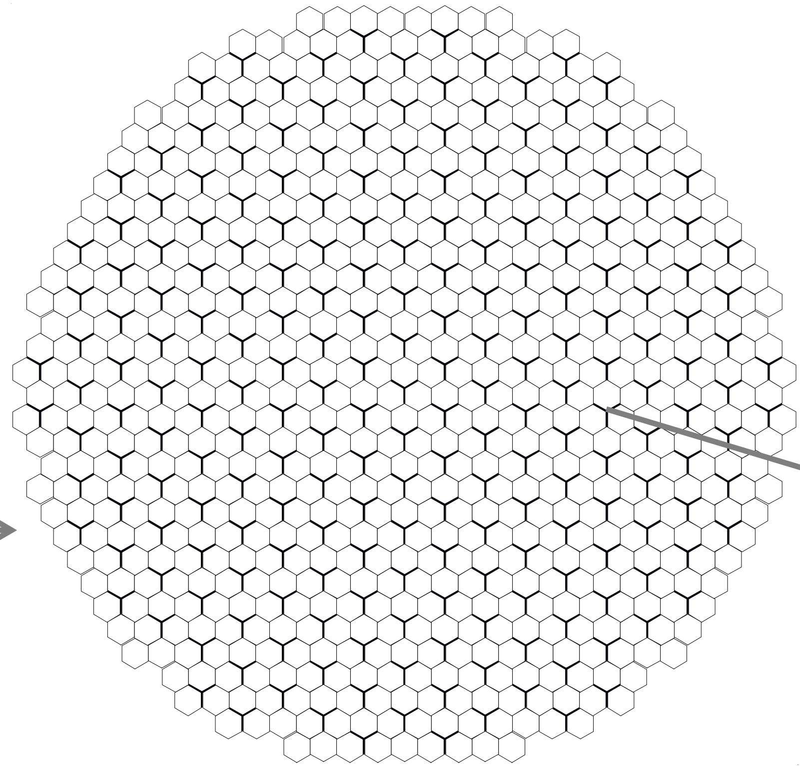
## Y-type Control rods are inserted between fuel bundles



Pressure vessel

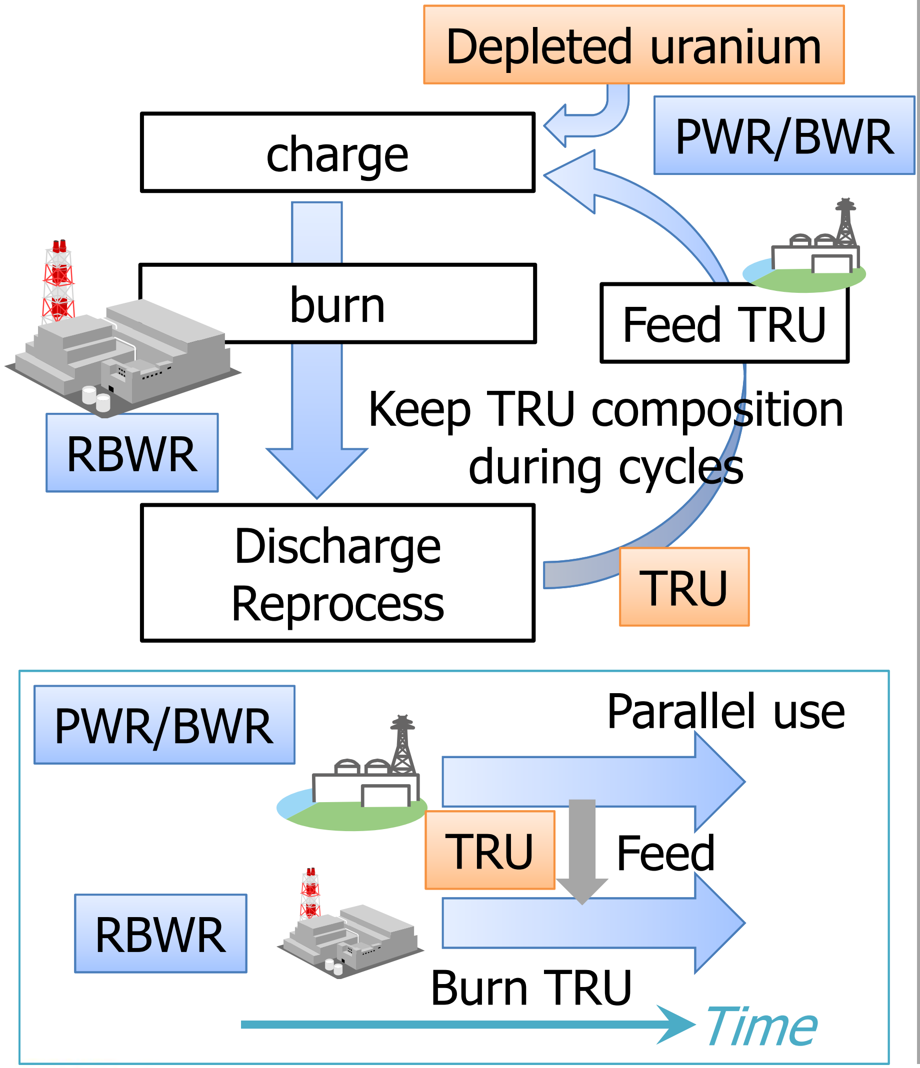


The number of
- fuel bundles: 720
- control rods: 223

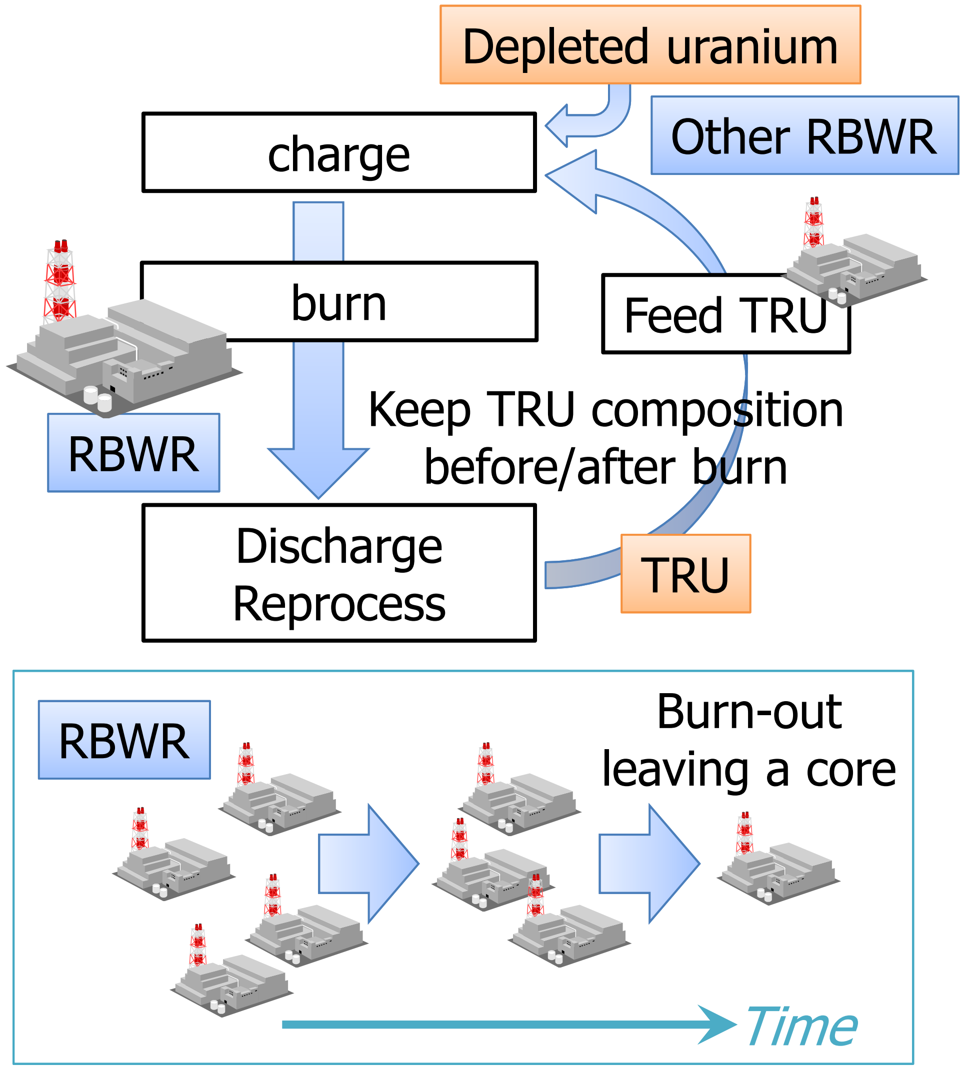

Y-type control rod

# 11. TRU burner types

## Burn TRU from PWR/BWR




## Burn-out almost all TRU

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# 12. Selection of moderator to fuel ratio

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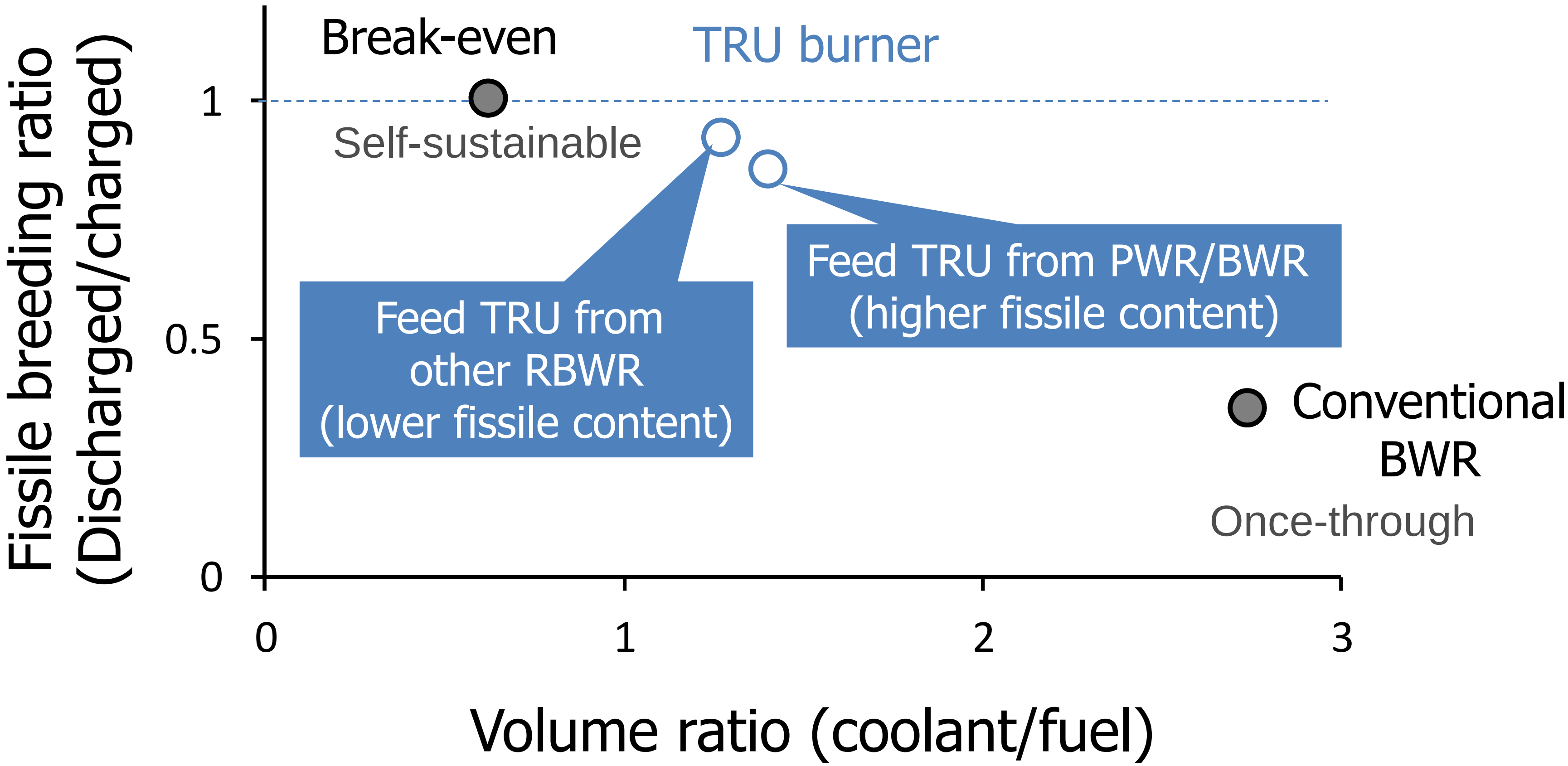
Proper fissile breeding ratio to achieve TRU multi-recycling is obtained by adjusting coolant(moderator)/fuel



# 13. Fuel concept for inherent safety

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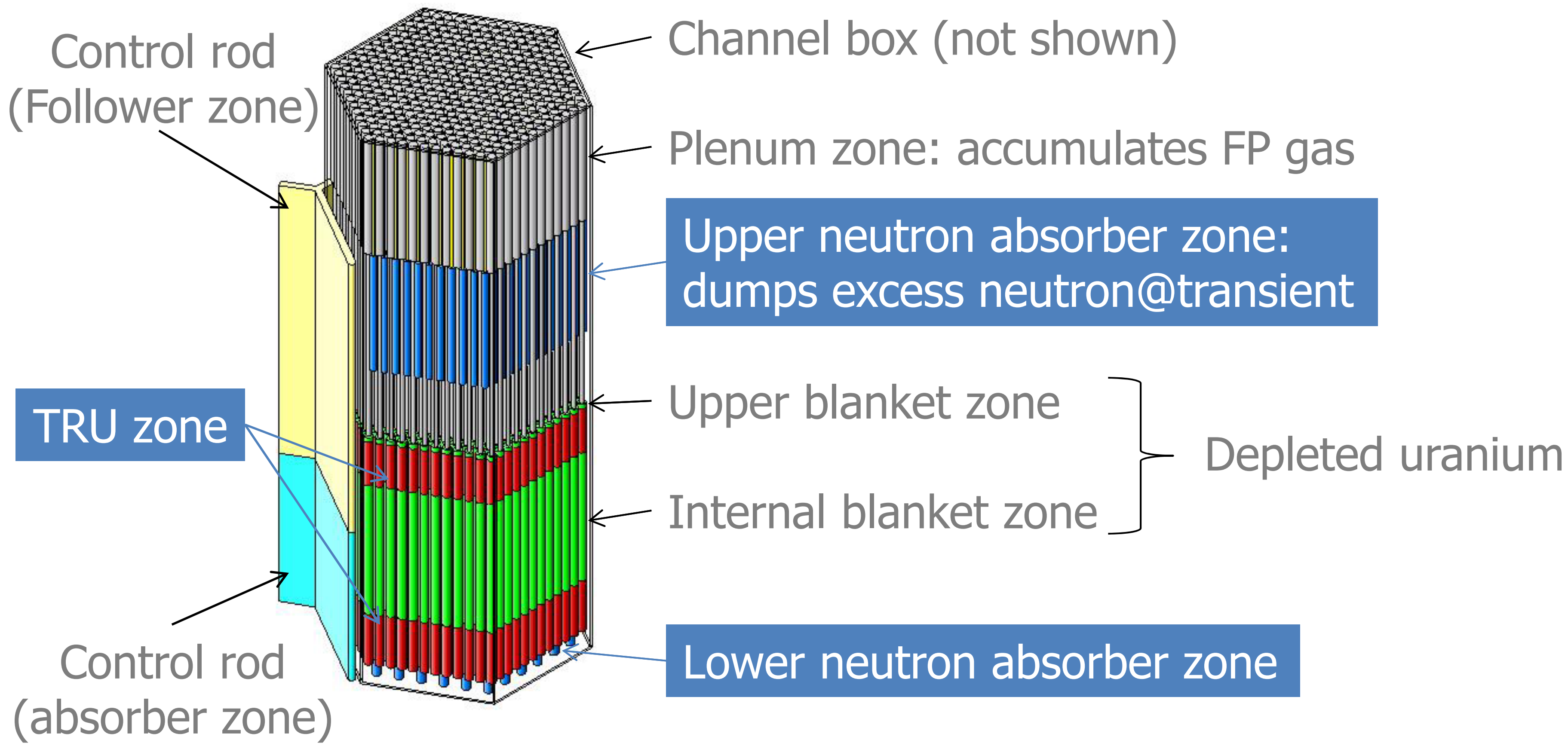
Void reactivity coefficient is kept negative by two fissile zone core with top/bottom neutron absorber zones




Fuel assembly

# 14. Performance as TRU burner

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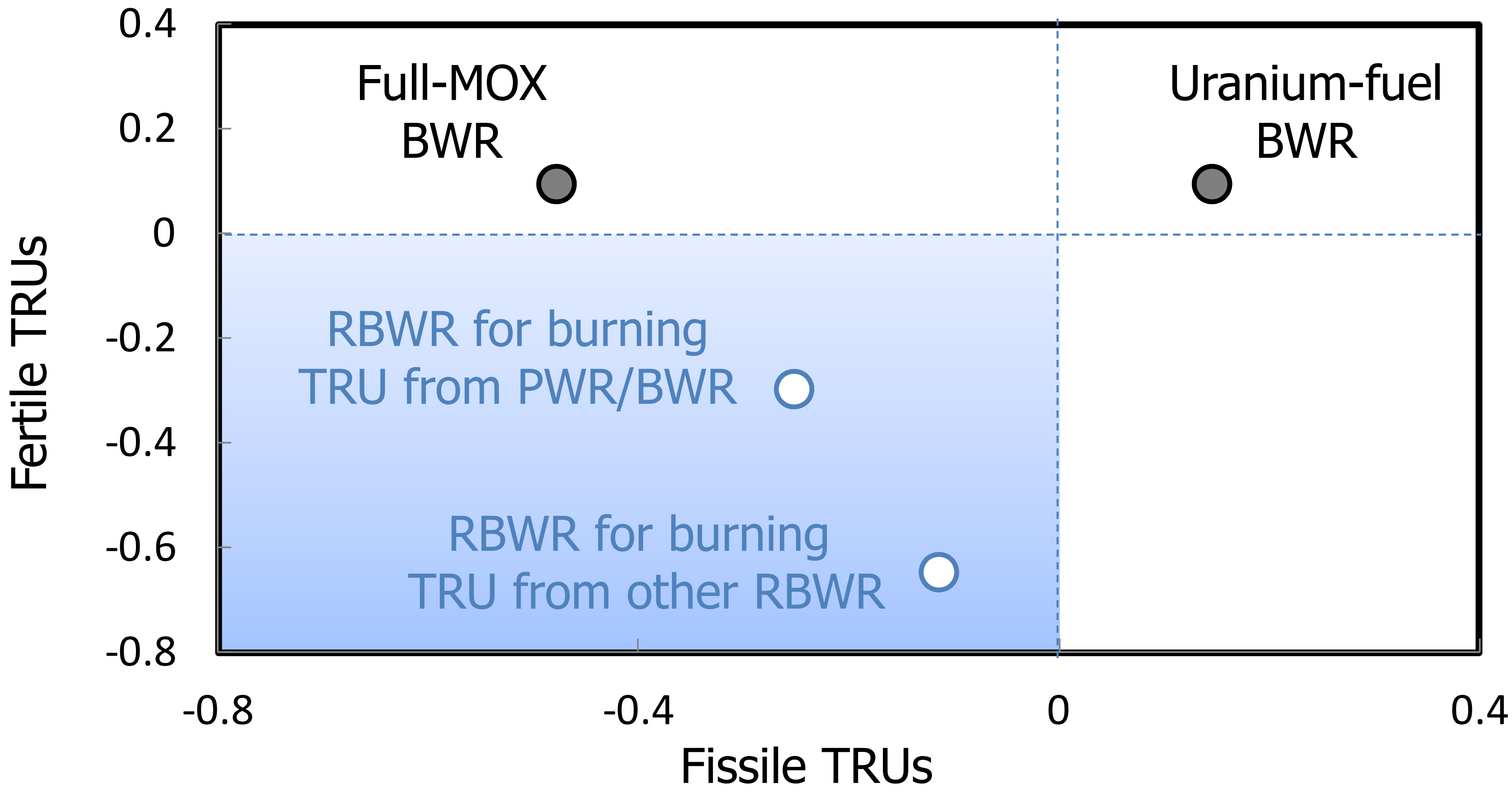
Fission not only fissile TRUs but also fertile TRUs at the rate more than twice the rate of TRU production by BWR




TRU production (burning) amount (ton/year)

# 15. Core specification and performance

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| Item | RBWR TRU burner | | ABWR |
|---|---|---|---|
| | For RBWR-TRU | For PWR/BWR-TRU | |
| Electrical power (MWe) | 1356 | 1356 | 1356 |
| Core height (mm) | 993 | 1025 | 3710 |
| No. of fuel bundles | 720 | 720 | 872 |
| No. of fuel rods | 397 | 397 | 74 |
| Fuel rods diameter (mm) | 7.4 | 7.2 | 11.2 |
| Fuel rod gap (mm) | 2.0 | 2.2 | 3.2 |
| Coolant flow rate (kt/h) | 38 | 24 | 58 |
| Core exit quality (%) | 21 | 36 | 13 |
| Void fraction (%) | 42 | 56 | 36 |
| Pressure drop (MPa)* | 0.20 | 0.06 | 0.21 |
| HM Inventory (t) | 77 | 76 | 150 |
| Puf/HM in TRU zone (w/o) | 13.9 | 25 | - |
| Burnup (GWd/t) | 55 | 65 | 45 |
| MLHGR (kW/ft) | 14.4 | 14.4 | 13.4 |
| MCPR | 1.3 | 1.28 | 1.3 |
| Void coef. ($\Delta$k/k/%void) | $-2\times10^{-4}$ | $-4\times10^{-4}$ | $-12\times10^{-4}$ |
| TRU production eff. (%)** | -51 | -45 | +22 |

* Active core region ** Net increase in TRUs divided by the total amount of fissioned actinides through the total fuel resident time in the core.

# 16. Hitachi's activity outline

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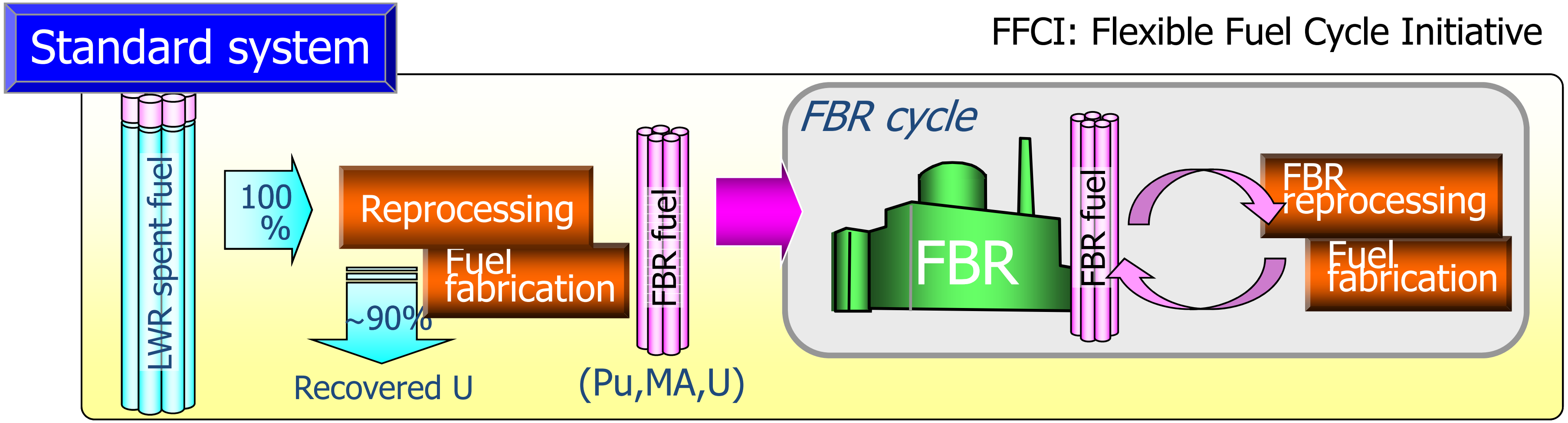
**Flexible fuel cycle**

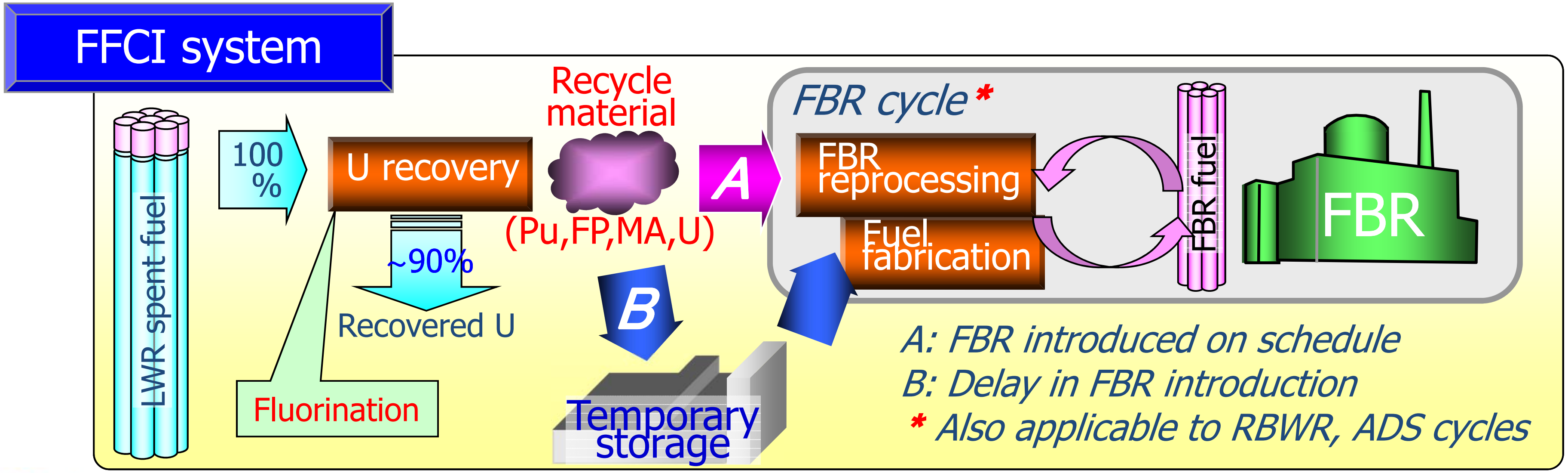
Adaptive to various fuel cycles,
debris management
Conducted as MEXT project

# 17. FFCI concept

Recover only U and store TRUs as recycle material with FPs
Meet FBR and various cycle deployment flexibly

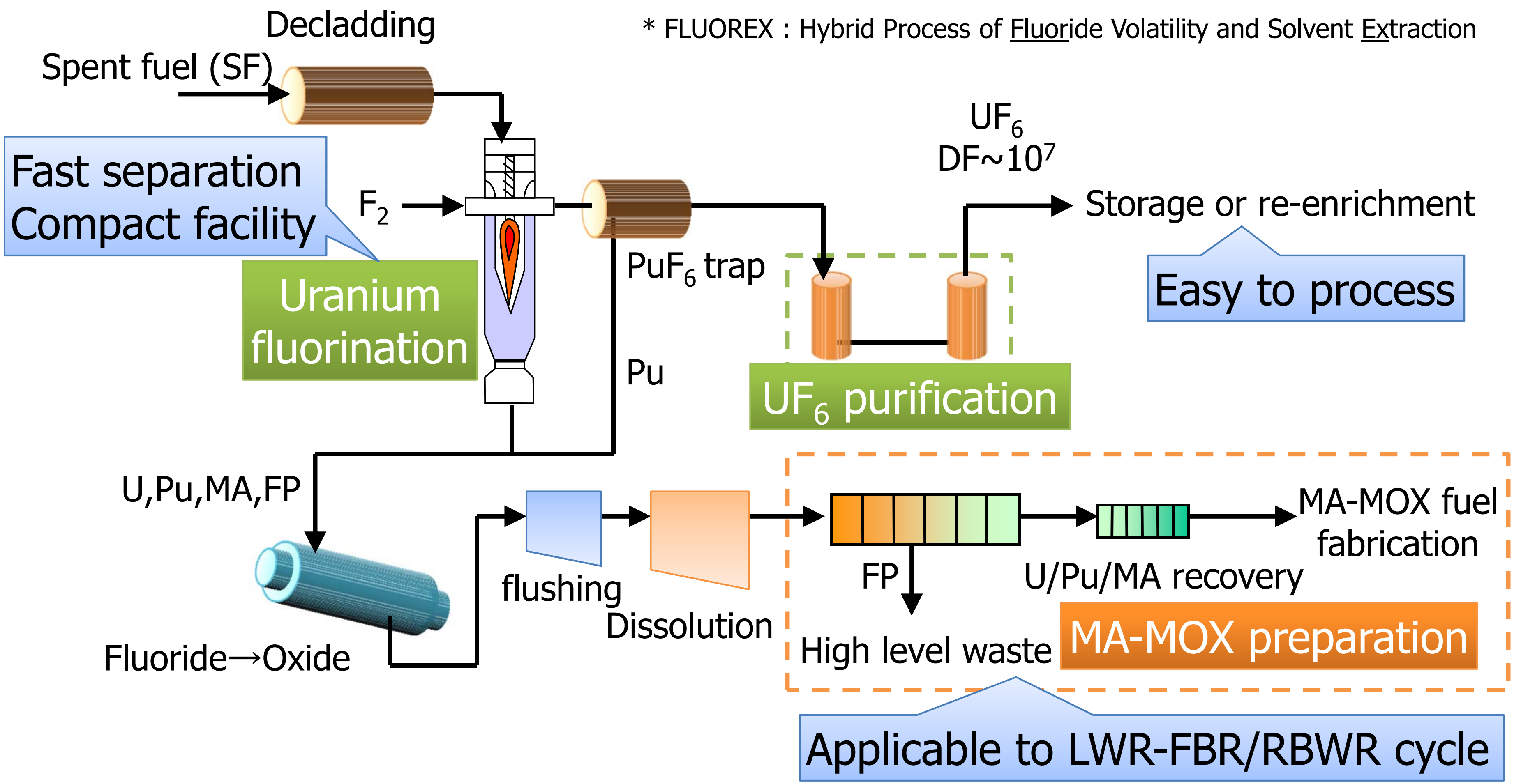
FFCI: Flexible Fuel Cycle Initiative



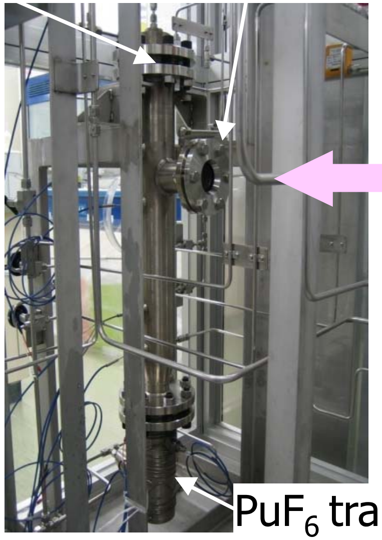
# 18. FLUOREX concept

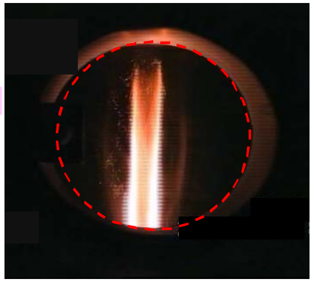
## Compact and flexible hybrid process of uranium (U) separation with fluorination and solvent extraction



# 19. FLUOREX development

## Applicability of fluorination was confirmed with simulated and actual spent fuel (SF) experiments

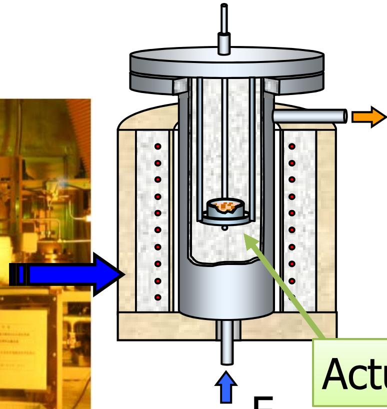



$UO_2$(solid)+$3F_2$(gas) → $UF_6$(gas)+$O_2$(gas)

Flame reactor
(~500g/h)

Test equipment
(hot cell)




Tube reactor
(~10g/batch)

<u>Simulated SF test</u>

<u>Actual SF test</u>

# 20. Application to debris treatment

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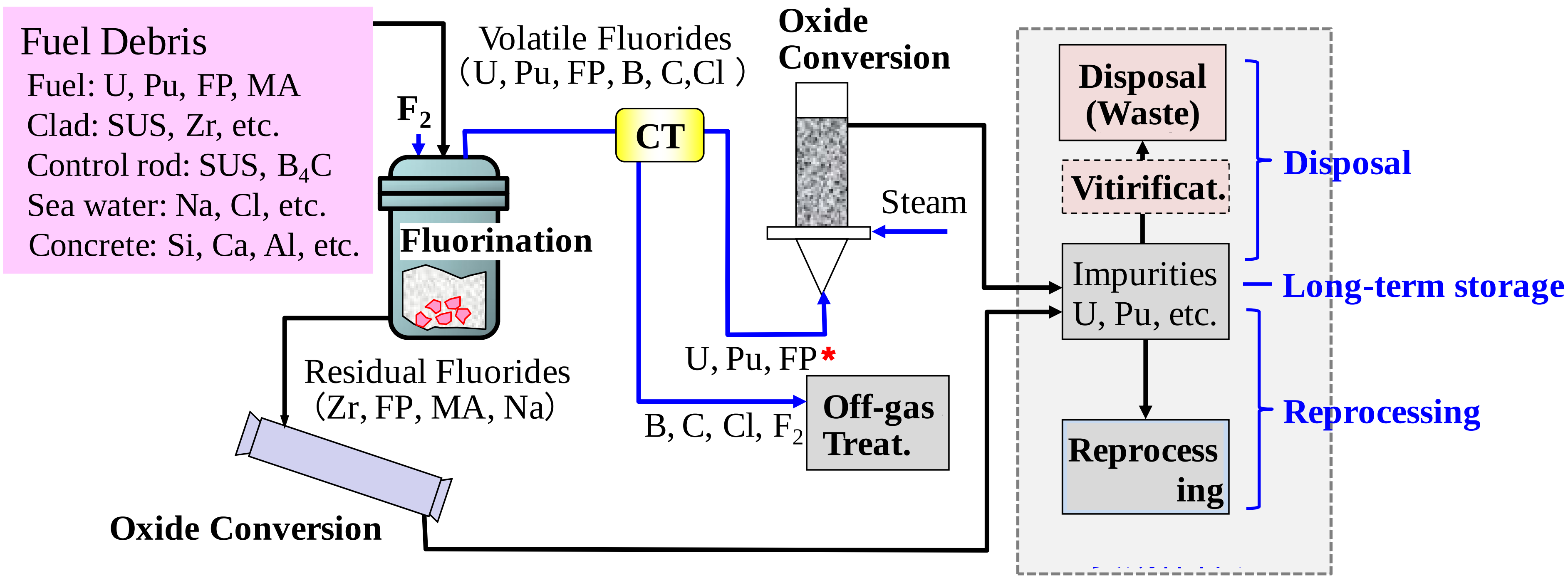
Decompose debris and separate U/Pu with compact facility
Flexibly respond to disposal, storage and reprocessing




* Easy accountancy

Fuel debris treatment process with fluorination method

# 21. Summary

- Hitachi contributes reduction of radioactive wastes:
  - Cooperates on national project through development of the advanced sodium-cooled MA burner reactor
  - Investigate feasibility of the TRU burner as an option for sodium-cooled fast reactor based on the BWR experience
  - Cooperates on national projects through development of reprocessing and fuel debris treatment technologies with fluorination

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# 23. Na plenum concept

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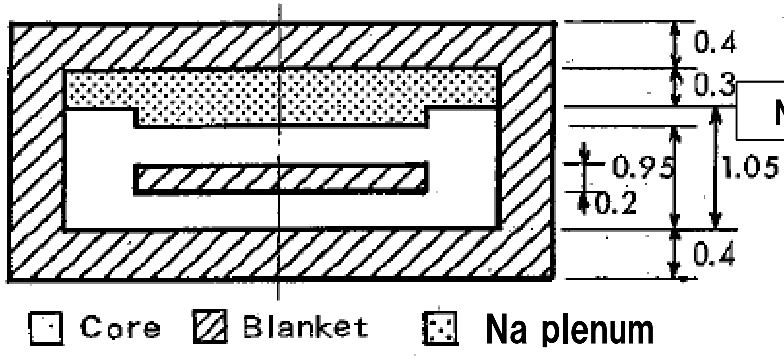
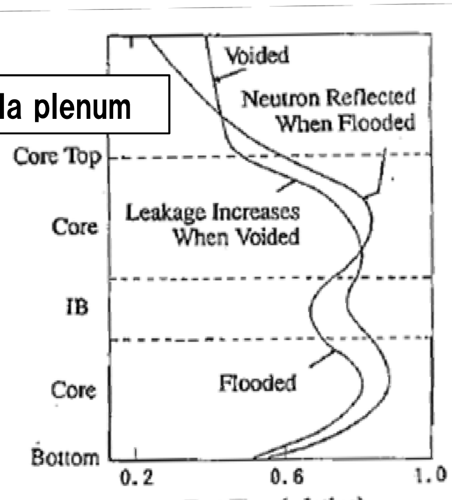
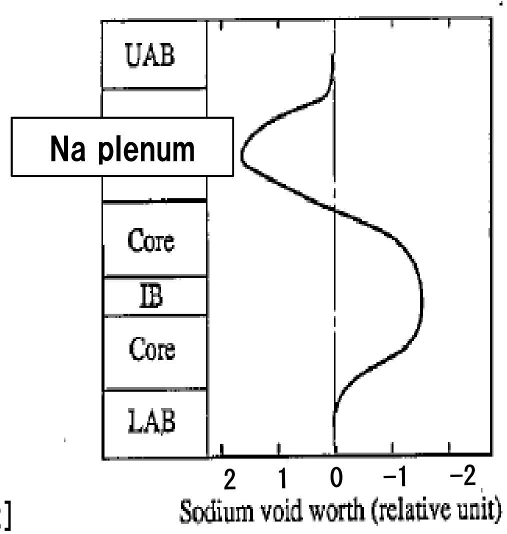



(c) AHC−Ⅱ

Fig.9 Core configurations [1]
(Vertical section, unit:m)




[2]
Fig.7 Axial flux distribution change upon Voiding




[2]
Fig.8 Axial sodium void worth distibution of AHC-II

[1] K. Kawashima, K. Fujimura, et al., :Study of the Advanced Design for Axially Heterogeneous LMFBR Cores, Proc. of FR91, Vol. I

[2] K. Kawashima, K. Fujimura, et al., :Conceptual Core Design to Enhance Safety Characteristics in MOX Fueled Large LMFBRs (I), -Neutronics and Transient Safety Performance Characteristics-, Proc. of ANP-92, Vol.II