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Study on Cross section Libraries for Shielding Design of Spent Fuel Cask and Cask Storage Facility

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1-1 Background

- **Dose limits** of regulation for casks in Japan
  - 2 mSv/h at the surface
  - 0.1mSv/h at the 1m point from the surface

- Typical **calculation method** for the licensing of casks

  [1] Dose calculation
  - Calculation code : Sn transport codes (ANISN,DORT)
  - Cross-section library : **DLC23/CASK**

  [2] Source term calculation
  - Calculation code : ORIGEN
  - Cross-section library : **BWRU**

◆ **These two** libraries are relatively old and some problems were pointed out

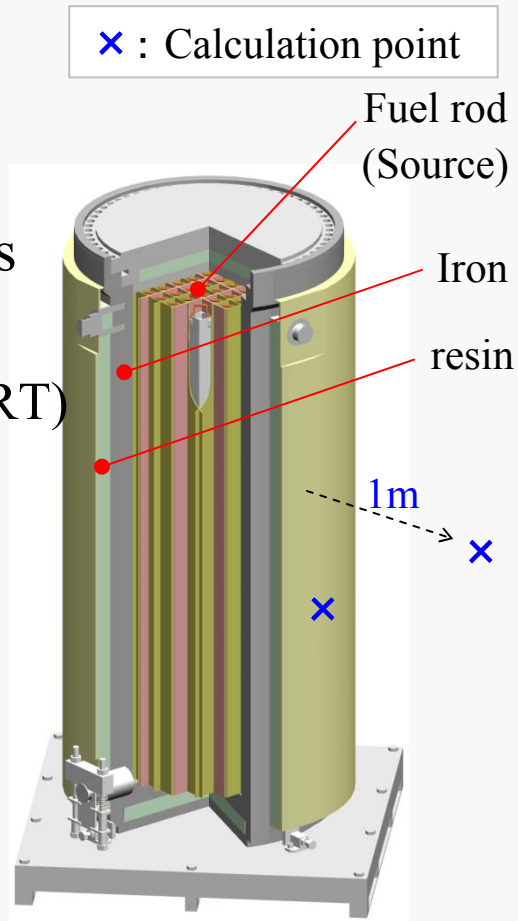

Fig. Spent fuel cask

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1-1 Background

- **Problems** pointed out previously

  [1] **DLC23/CASK** (Dose calculation)

  - Calculation results **underestimate** the measurement values in some case such as the model with thick iron

  [2] **BWRU** (Source term calculation)

  - Calculation results for low burn-up fuels **underestimate** the measurement values of neutron
  - Burn-up level of recent fuels is out of range covered by BWRU

- While **some other updated libraries** are available to use

  [1] Dose calculation

  - **MATXSLIB** (JENDL3.3)
  - **VITAMIN-B6** (ENDFB-VI)

  [2] Source term calculation

  - **ORLIB-J33** (JENDL3.3)
  - **GE8x8-4** (ENDFB-VI)

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1-2 Purpose

- **Purpose**
  (i) Confirm the safety margins of results conducted by using currently-used library
  (ii) Assess the applicability of the updated libraries

- **Contents** of this presentation

  [1] Dose calculation
  - **(i)** **C**alculate neutron dose in iron
  - **(ii)** **C**alculate gamma dose in iron
  - **(iii)** Discuss the applicability of each libraries

  [2] Source term calculation
  (i) Define the calculation conditions (burn-up level)
  (ii) Discuss the applicability of each libraries

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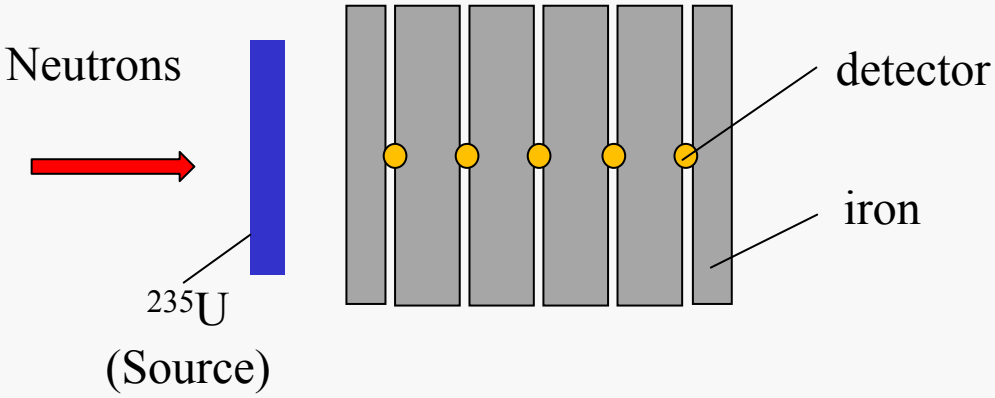
2 -1 Neutron dose calculation in iron

- Configuration of benchmark test[1] and calculation model

Configuration of benchmark test



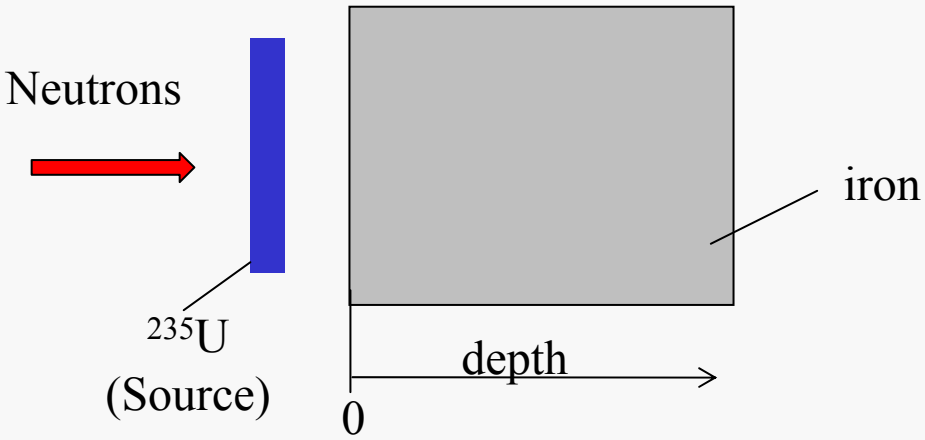
Detectors and its working energy range

Detector	Working energy range
$^{32}S(n, \gamma)$	1.6 MeV < E
$^{115}In(n, n')$	0.4 MeV < E
$^{103}Rh(n, n')$	40 keV < E
Cd{$^{197}Au(n, \gamma)$	0.55eV-100keV

}

[1] J. Butler, et al.,SINBAD ABSTRACT NEA-1517/34
Winfrith Iron Benchmark Experiment (ASPIS)

Calculation model



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2 -1 Neutron dose calculation in iron

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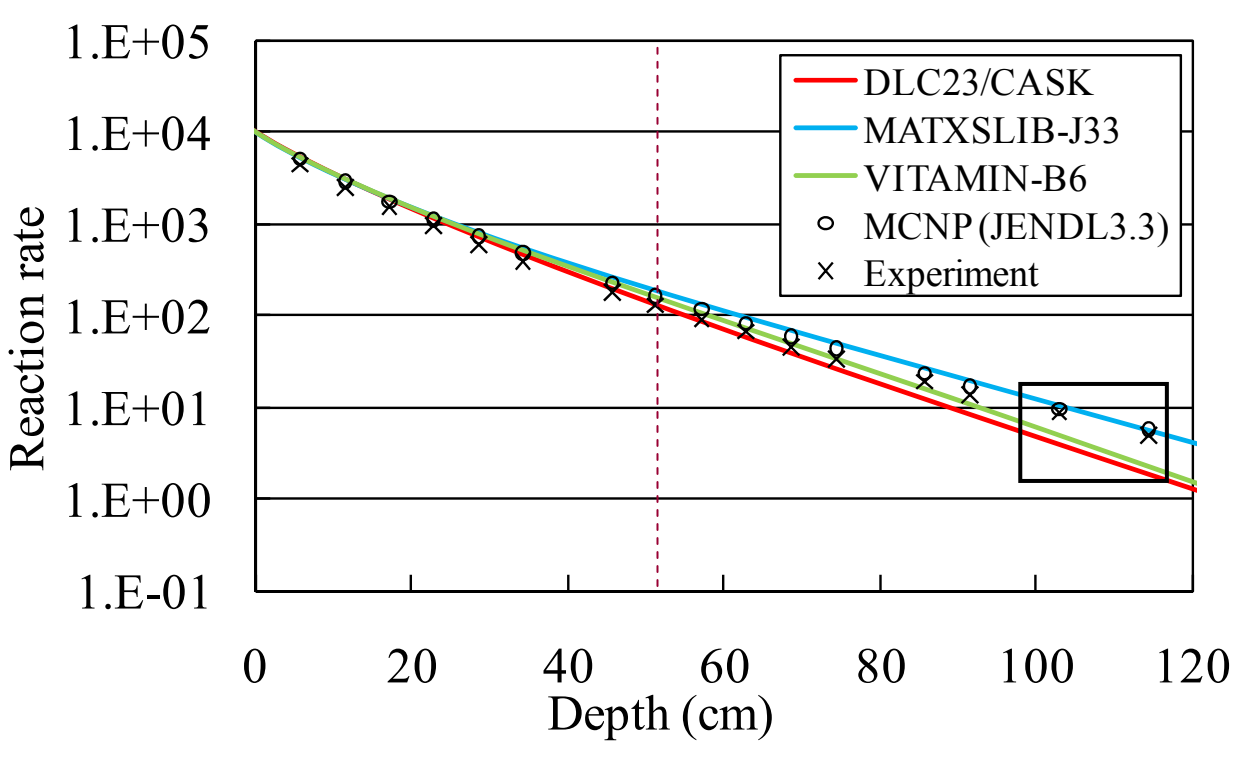
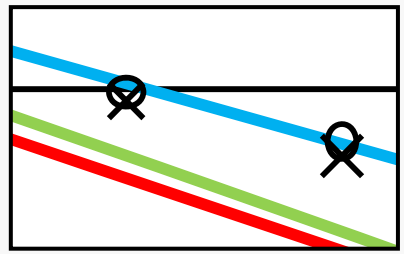
Attenuation of reaction rate for ^{103}Rh in iron





- DLC23/CASK and VITAMIN-B6 underestimate the measurement for iron more than 50cm thick.
- MATXSLIB shows good agreement with the measurement

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2 -1 Neutron dose calculation in iron

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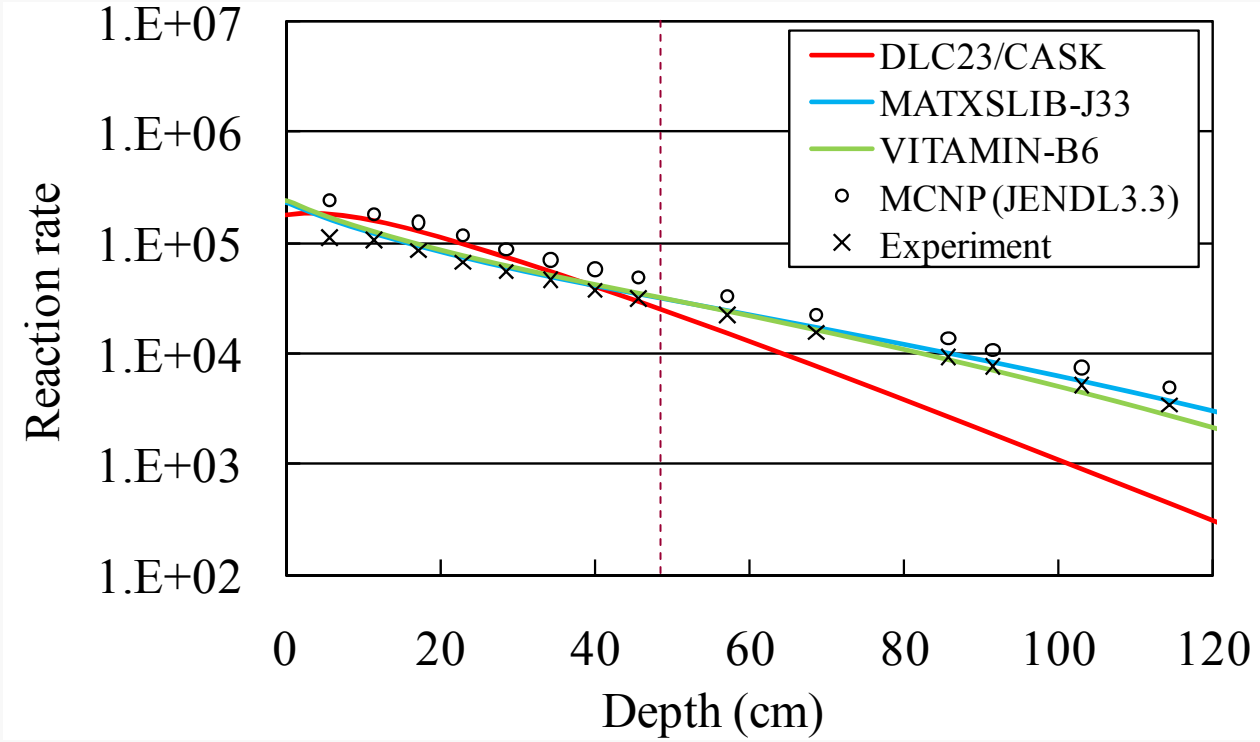
Attenuation of reaction rate for ^{197}Au in iron



- DLC23/CASK underestimate the measurement for iron more than 50cm thick

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2 -2 Gamma dose calculation

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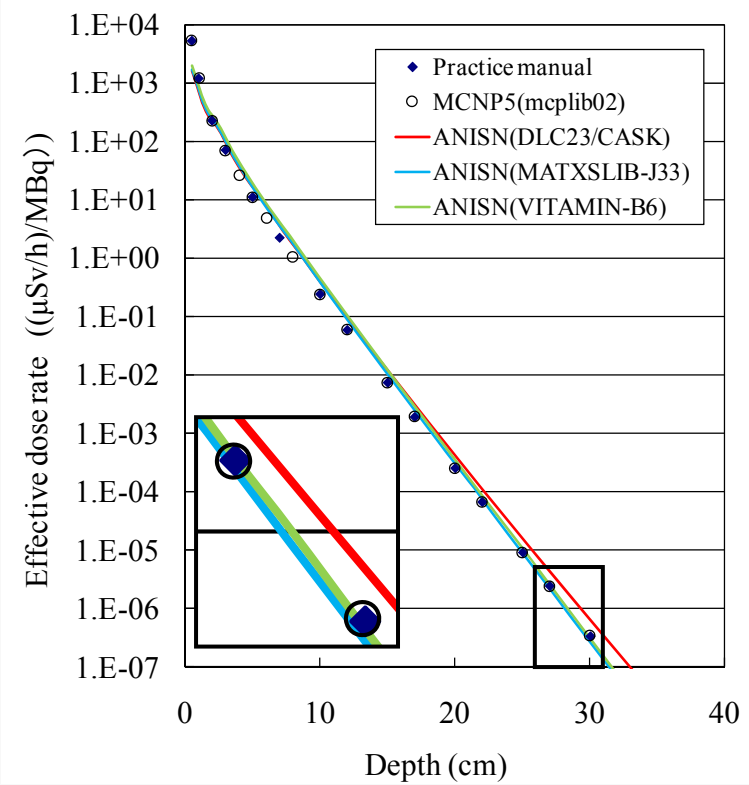
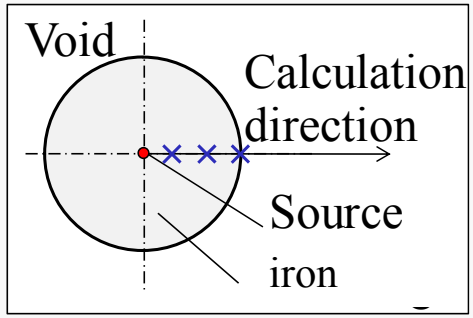
Gamma dose attenuation in iron





Library	Energy-group structure
mcplib02 (MCNP5)	- (continuous)
MATXSLIB-J33	42 groups
VITAMIN-B6	42 groups
DLC23/CASK	18 groups
MATXSLIB-J33 (Edt.)	18 groups

- Only DLC23/CASK overestimated the measurement
- MATXSLIB-J33(Edt.) is an edited library having 18 energy-group structure as contracted from MATXSLIB-J33.

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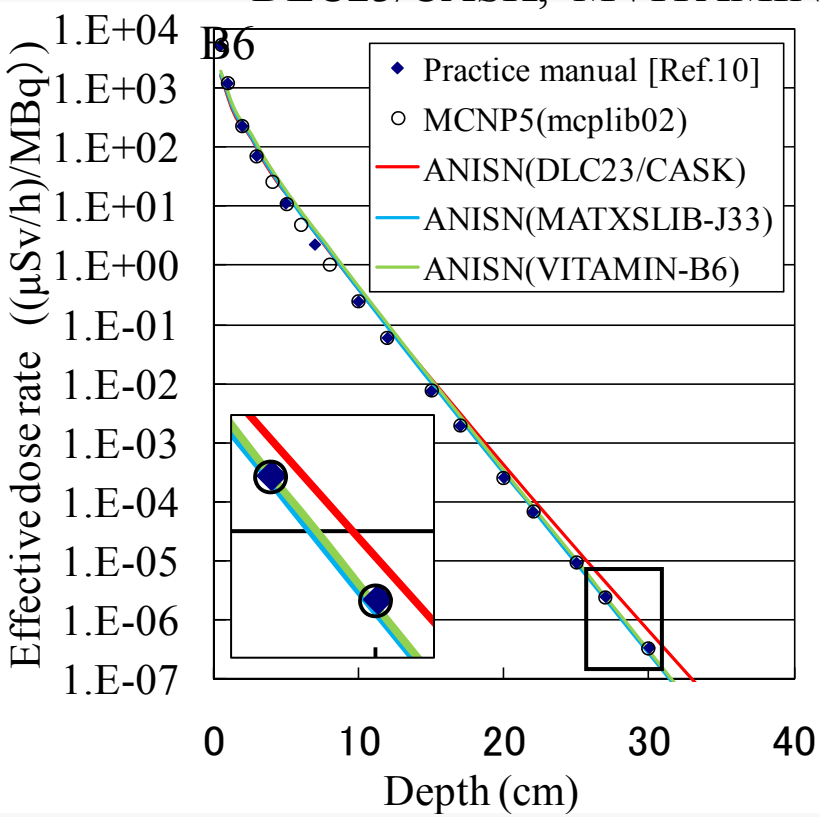
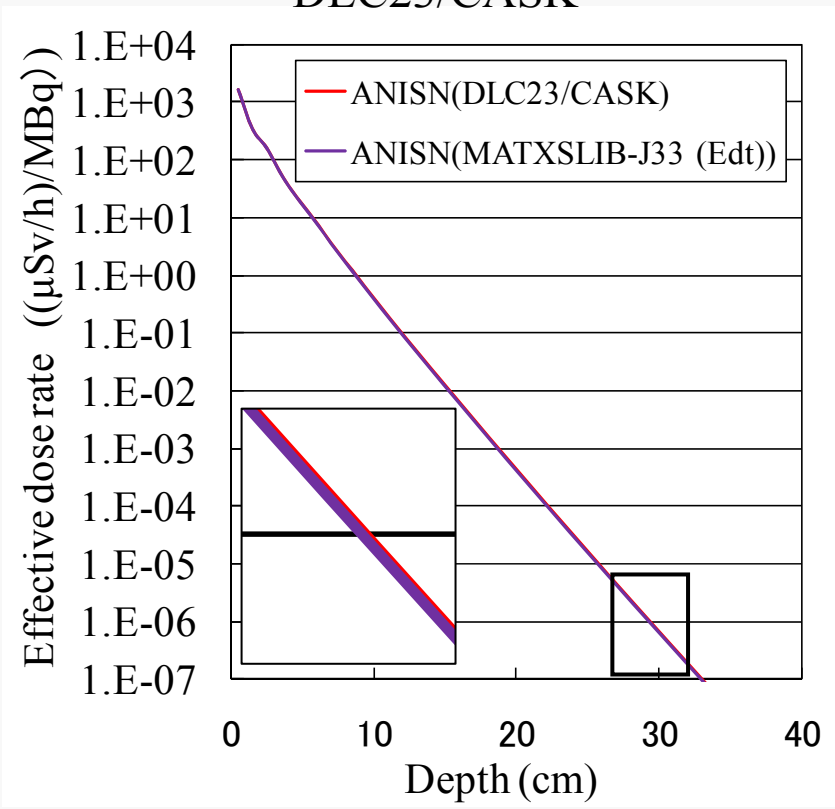
2 -2 Gamma dose calculation

Libraries
- MATXSLIB-J33
- DLC23/CASK, MVITAMIN-B6



Libraries
- **MATXSLIB-J33 (Edt.)**
- DLC23/CASK



- Overestimation shown by using DLC23/CASK caused by the coarse energy-group structure

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- Comprehensive evaluation of applicability to shielding design

	DLC23/CASK	MATXSLIB-J33	VITAMIN-B6
Neutron	△ Underestimation	○ Good	△ Underestimation
Gamma	△ Overestimation	○ Good	○ Good
Comprehensive	△ Fair	○ Good	○ Good

◆ DLC23/CASK and VITAMIN-B6 **can be applied** to shielding design of general shaped casks with iron less than 50cm thick.

◆ MATXSLIB-J33 would be **better** library due to its better agreement with measured values.

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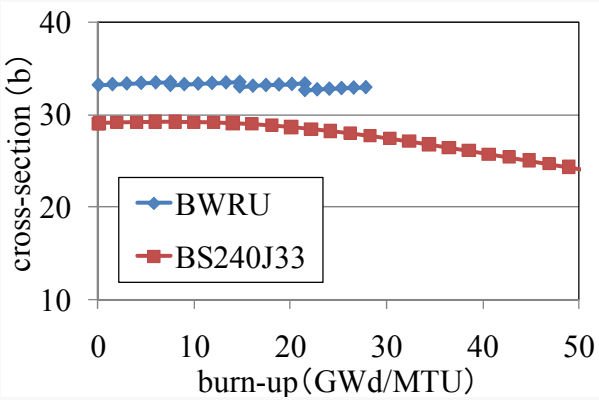
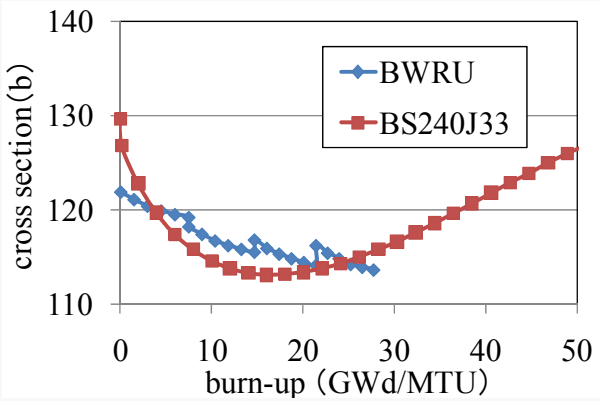
3 -1 Background

- **Problems** of **BWRU** pointed out previously
  - Calculation results for low burn-up fuels **underestimate** the measurement values of neutron
  - Burn-up level of recent fuels is out of range covered by BWRU

  (burn-up range covered by BWRU : less than 27.5 (GWd/t)



Pu242(n, g)



Pu239(n, fission)

- **Purpose**
  - Confirm the safety margins of the total amount of neutron conducted by using **BWRU** and updated libraries (**ORLIB-J33, GE8x8-4**)

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3 -2 Examination method

- **Benchmark**
  - SF-98[2] was selected as high burn-up
    - Type of reactor : BWR
    - Initial enrichment of ^{235}U: 3.91 (wt%)
    - Average void ratio : 43 (%)
    - Burn-up : 27-44 (GWd/t)

- **Examination method**
  - Total amount of neutron was regarded as the same amount of ^{244}Cm.
    (The contributing rate of ^{244}Cm was more than 90%)
  - Total amount of ^{244}Cm was calculated as sum total at five points as shown in right Fig.

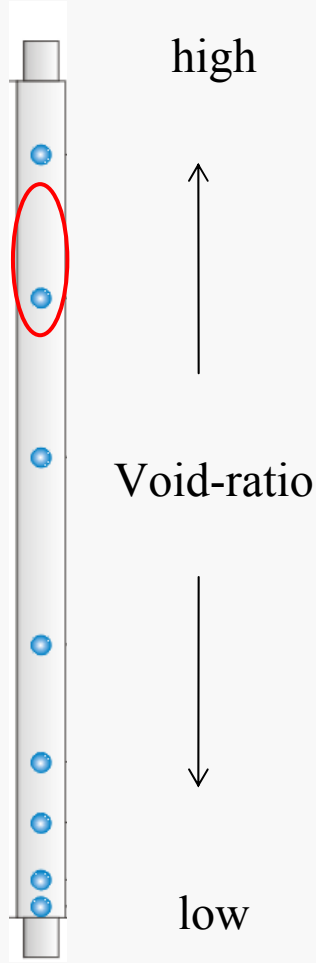

Fig. Sampling points of the fuel rod

[2] Science and Technology Agency of Japan,
Post Irradiation Examination for the Spent Fuel Samples

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3 -3 Result and discussion

- **Calculation conditions**
  - Same condition as benchmark except void-ratio
  - Void-ratio

    BWRU : 40% (Library constraint)

    ORLIB-J33 : 40%, 70% (Library constraint)

- **Calculation results**
  - Relative amount of ^{244}Cm calculated as C/E

	ORIGEN2.2		
	BWRU	ORLIB-J33 (JENDL3.3)	
	Void ratio = 40	**Void ratio = 40**	**Void ratio = 70**
C/E (Total of 5 point)	**1.03**	**0.92**	**1.14**

- BWRU : results have several percent safety margins compared to measured values
- ORLIB-J33 : Void-ratio is recommended to be set by 70% to avoid underestimation

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3 -3 Result and discussion

- **Calculation conditions**
  - Same condition as benchmark except void-ratio
  - Void-ratio

    GE8x8-4 : 43%, 50%, 60% (No constraint)

- **Calculation results**
  - Relative amount of ^{244}Cm calculated as C/E

	ORIGEN-ARP		
	GE8x8-4 (ENDF/B-VI)		
	Void ratio = 43	Void ratio = 50	Void ratio = 60
C/E (Total of 5 point)	0.96	**1.02**	**1.09**

◆ GE8x8-4 can be applied to shielding design when the void-ratio is set appropriately

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4 Conclusion

[1] Dose calculation

DLC23/CASK and VITAMIN-B6 **can be applied** to shielding design of general shaped casks with iron less than 50cm thick.

MATXSLIB-J33 would be **better** library due to its better agreement with measured values.

[2] Source term calculation

BWRU will be able to applied to shielding design to define the neutron strength of high burn-up fuel and results have several percent safety margins.

ORLIB-J33 and GE8x8-4 also can be applied to shielding design by setting the void-ratio appropriately.

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END

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