2017 NCSD Topical Meeting

Accident Analysis of Spent Fuel Storage and Transportation Cask with Gd based Neutron Absorber

UNIST
Department of Nuclear Engineering
Mi Jin Kim, Dong-Seong Sohn

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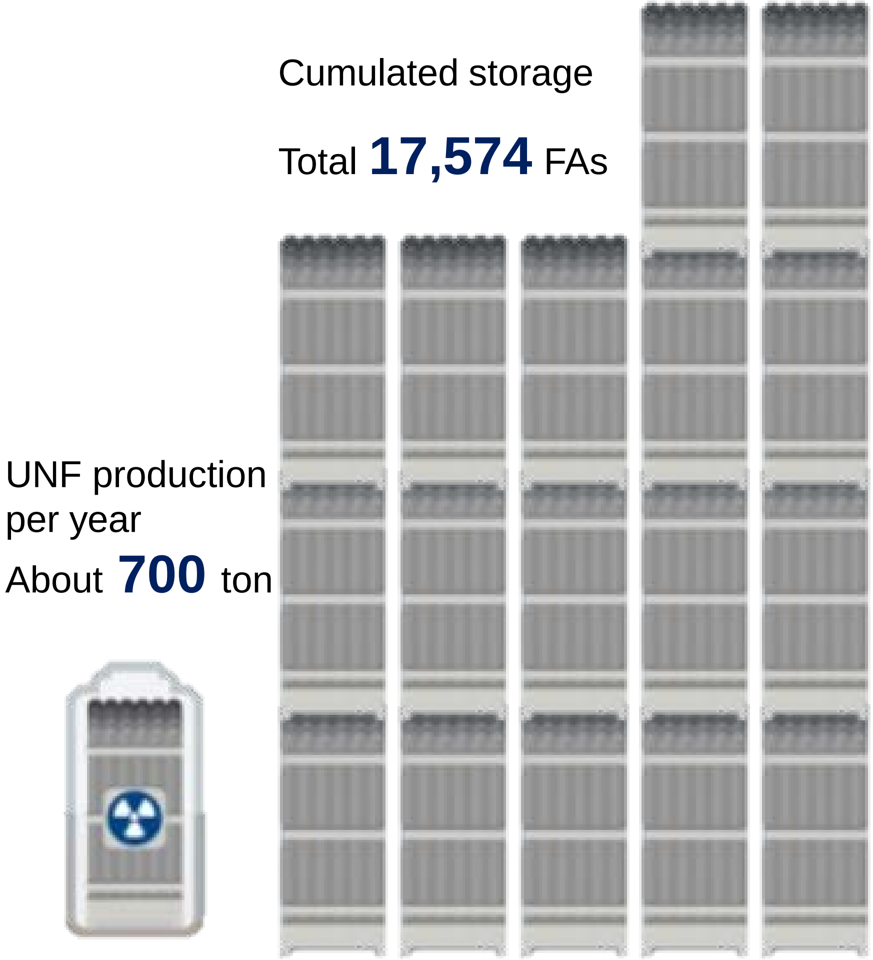
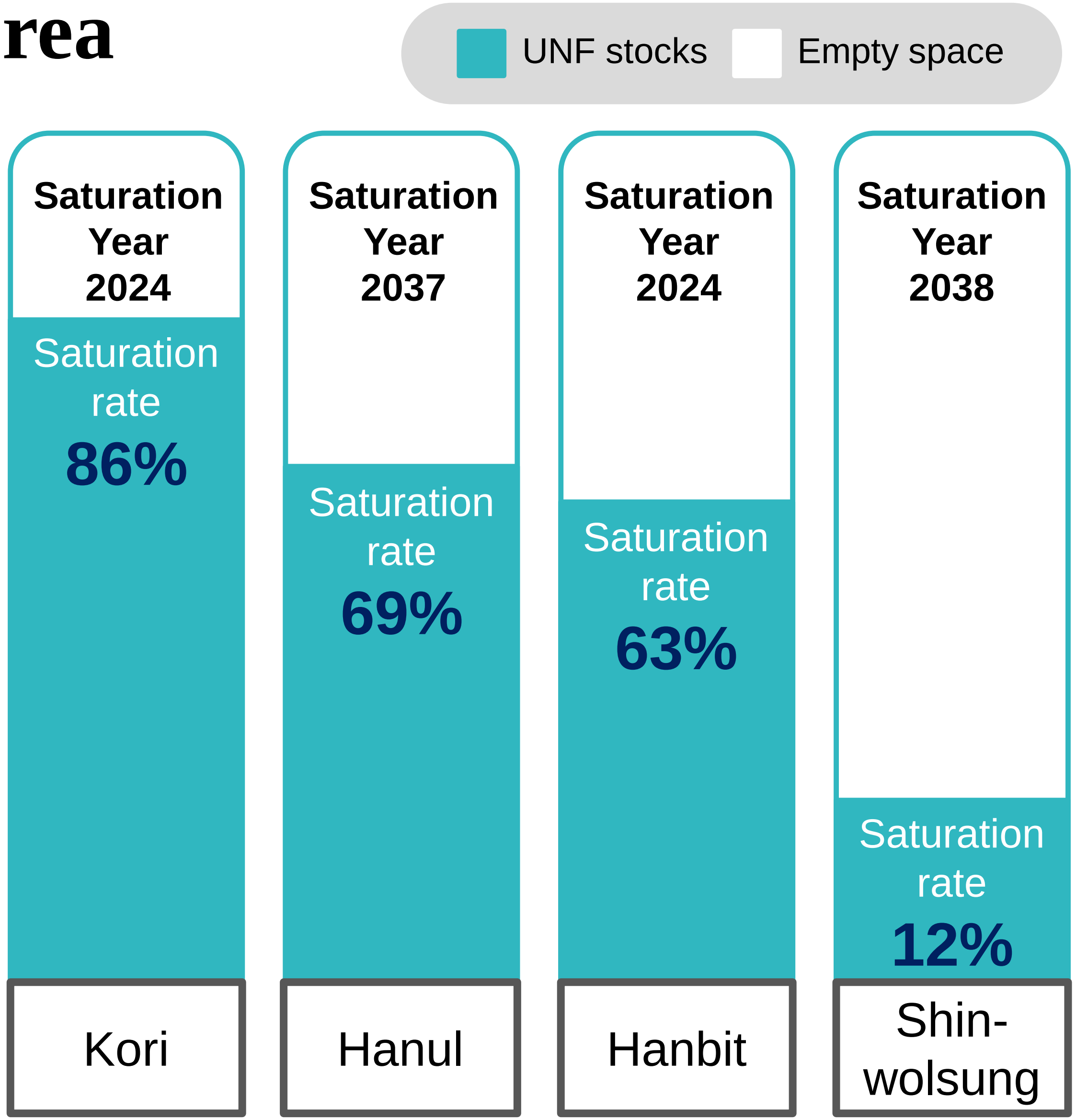
I. Introduction

□ Storage status in Korea





[1] KHNP, 2017 [2] NARS Report No. 307, 2017

□ Background

- The shortage of spent nuclear fuel (SNF) storage in SNF pool has been issued.
- Some alternatives are suggested such as:
  - **High density SNF pool**
  - **SNF storage and transportation cask**
- It is essential to **develop advanced neutron absorber** for effective storage of SNF.
- Also, there's no commercial domestic neutron absorber in Korea.

1.2 Neutron absorber material

□ Common material

- BORAL
- METAMIC
- Borated Stainless Steel

Boron compound

However, boron compound generates helium bubble when boron reacts with neutron. These helium bubbles enhance defect production and lead to further degradation. Also, blistering from BORAL neutron absorber has been noticed. This could reduce free clearance.

➡ Not good for long-term storage

1.2 Neutron absorber material

□ New material: Gadolinium

- Very high absorption cross section in thermal region
- Relative abundance of Gd-155, 157 (30.45 a/o) is 1.5 times higher than B-10 (19.9 a/o)

Element	Abundance (a/o)	σ_a (barns)
B-10	19.9	3,840
B-11	80.1	0.005
Gd-152	0.20	1,400
Gd-154	2.18	290
Gd-155	14.80	62,540
Gd-156	20.47	12
Gd-157	15.65	255,000
Gd-158	24.84	7
Gd-160	21.86	1.8

□ Regulation of criticality analysis for SNF storage and transportation cask system

- The criticality safety should be ensured to be used as neutron absorber in the spent nuclear fuel storage system.

- The regulation and standards for spent fuel dry storage and transportation system is 10CFR71.55, NUREG-1536 and NUREG-1617.

→ "***The effective neutron multiplication factor**, keff, including all biases and uncertainties at a 95-percent confidence level, **should not exceed 0.95** under all credible normal, off-normal, and accident-level conditions.*"

[3] 10 CFR Part 71, U.S. NRC
[4] NUREG-1536, U.S. NRC
[5] NUREG-1617, U.S. NRC

II. Analysis methodology

2.1 Analysis method

□ Computer program

- Program : **KENO-Va** in SCALE 6.2 code system
  – Monte Carlo criticality computer code for criticality safety analysis tools

- Cross-section library : ENDF/B-VII.0 (238 group)

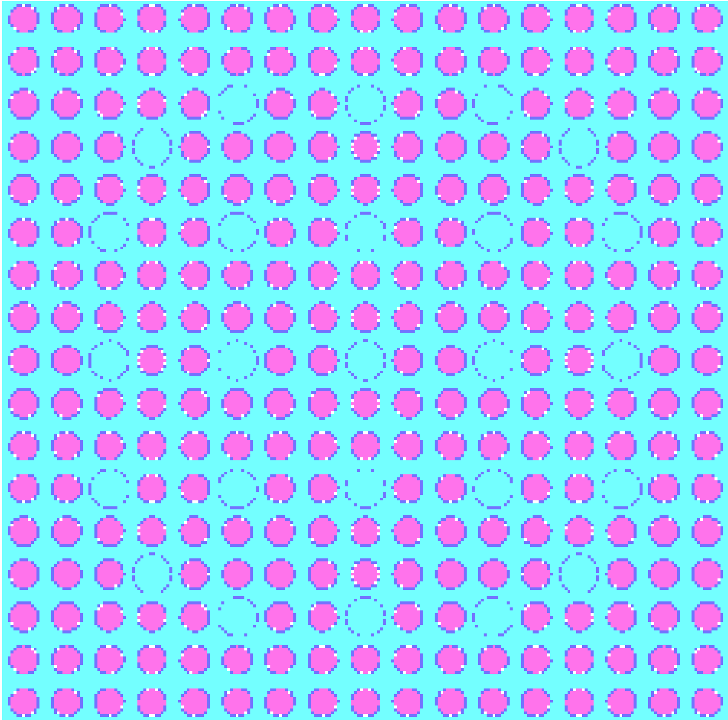
- Number of cycle : 2000

- Number of neutron generation per cycle : 8000

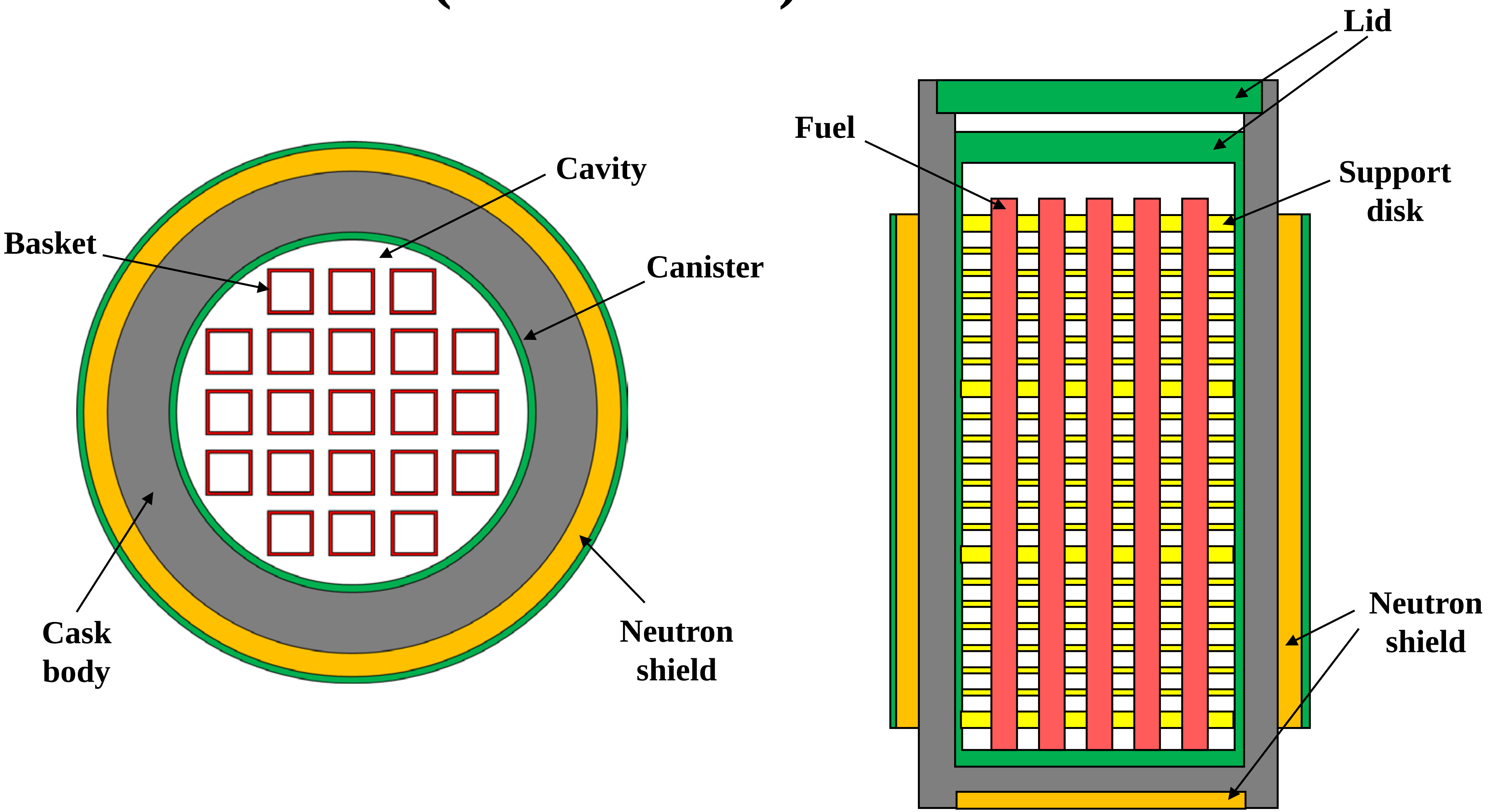
- Average standard deviation : 0.00007-0.00024

□ Fuel assembly model

- 17X17 array WH OFA type fuel
- Fresh fuel (enrichment and composition)
- U-235 enrichment : 4.5 w/o
- Fuel rod UO_2 density : 95.25% of theoretical density



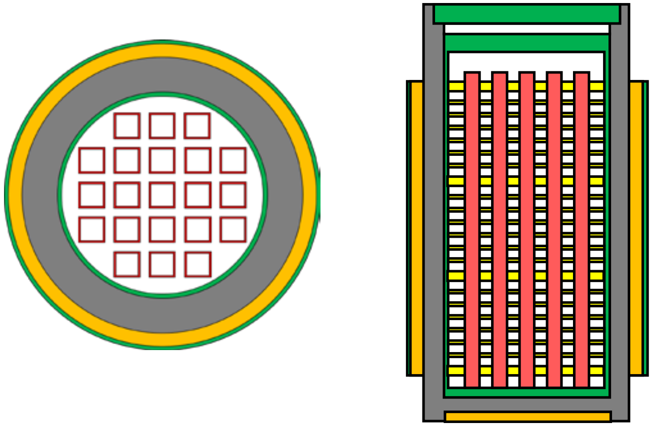
□ Cask model (KORAD-21)



[5] 14220-P1-N-TR-006, KORAD (2012)

2.2 Analysis model

□ Cask model (KORAD-21)



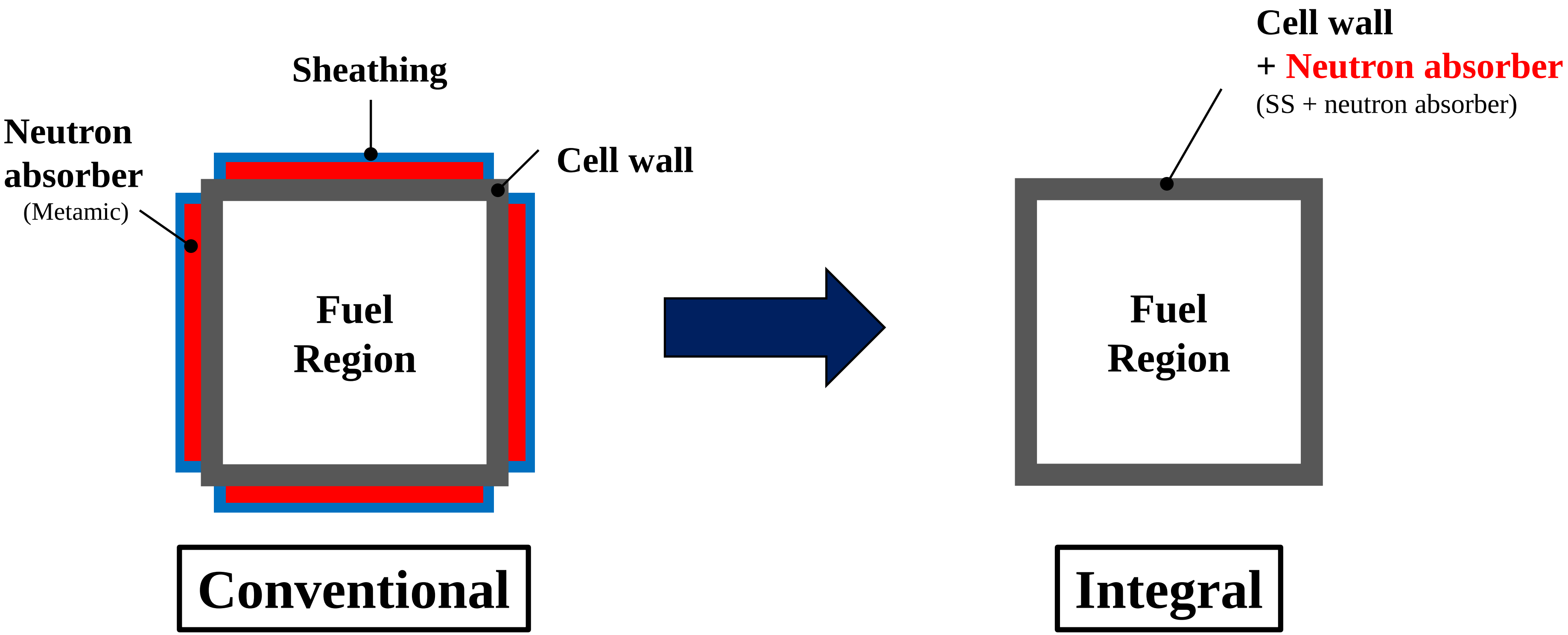
- Dual purpose: Storage and transportation
- Capacity: 21 FAs
- 22 support disks in axial direction

Component	Material
Canister	Stainless steel
Cask body	Carbon steel
Support disk	Stainless steel
Neutron shield	Resin
Lid	Stainless steel

[5] 14220-P1-N-TR-006, KORAD (2012)

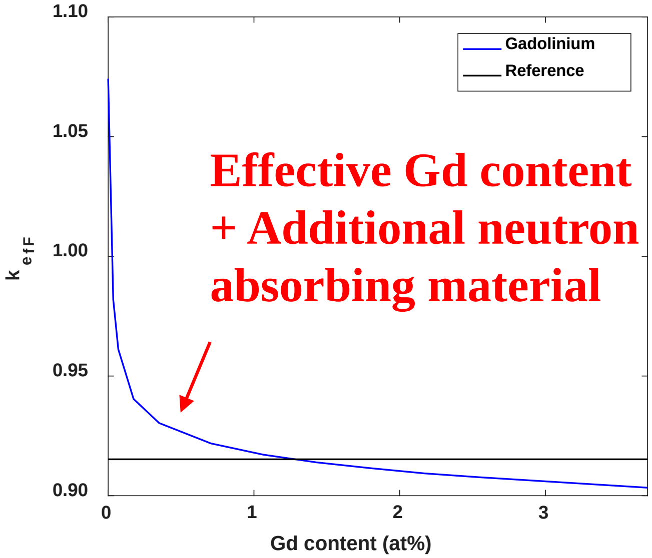
□ Basket model

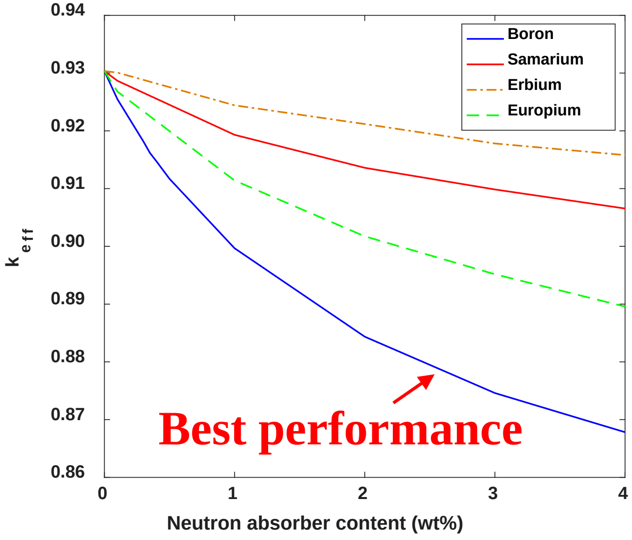
- No separate neutron absorber or sheathing
- Neutron absorbing materials are melt in stainless steel

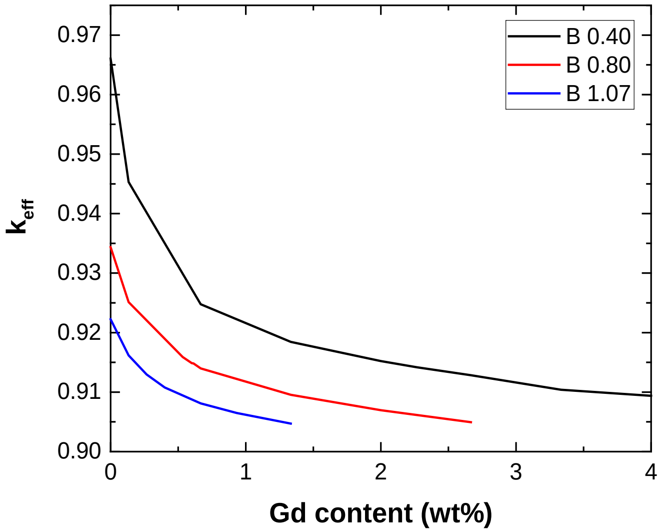


2.2 Analysis model

□ Optimizing neutron absorber contents







Neutron absorber content: Gd 1 wt% + B 0.4 wt%

III. Results and discussion

3.1 Normal condition

□ Dry condition

- The normal condition is calculated in dry condition.
- The coolant in dry condition is dry air (0.001293 g/cm^3)

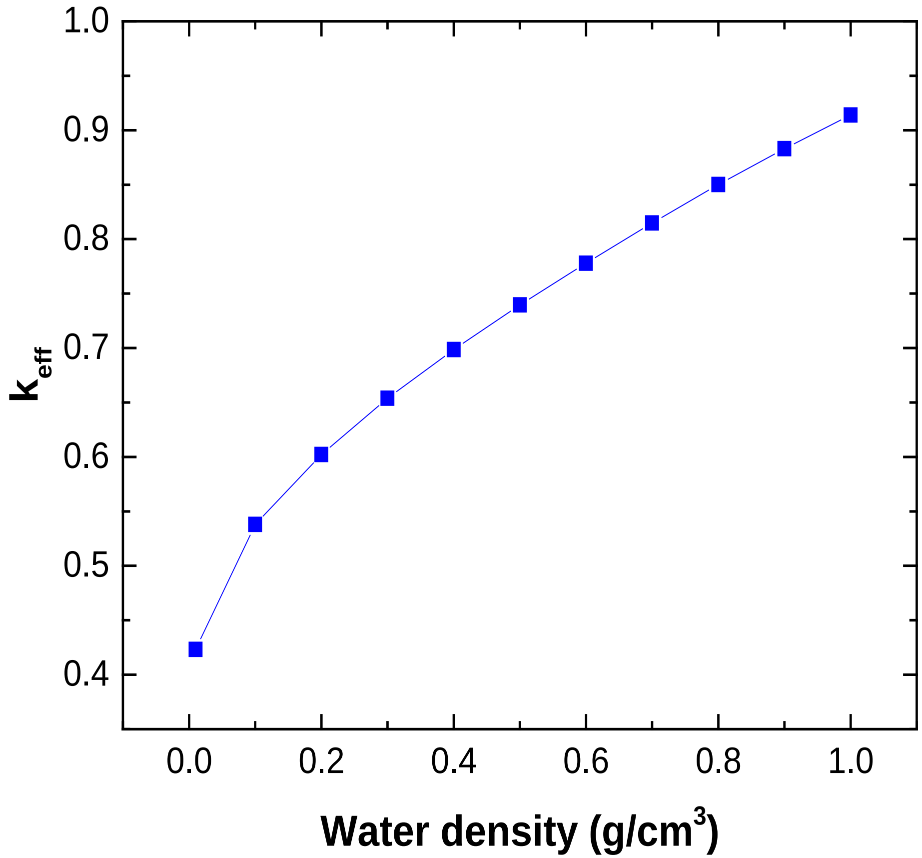
Coolant condition	k_{eff}	SD*
Dry condition (Dry air)	0.38234	0.00008

* Standard deviation

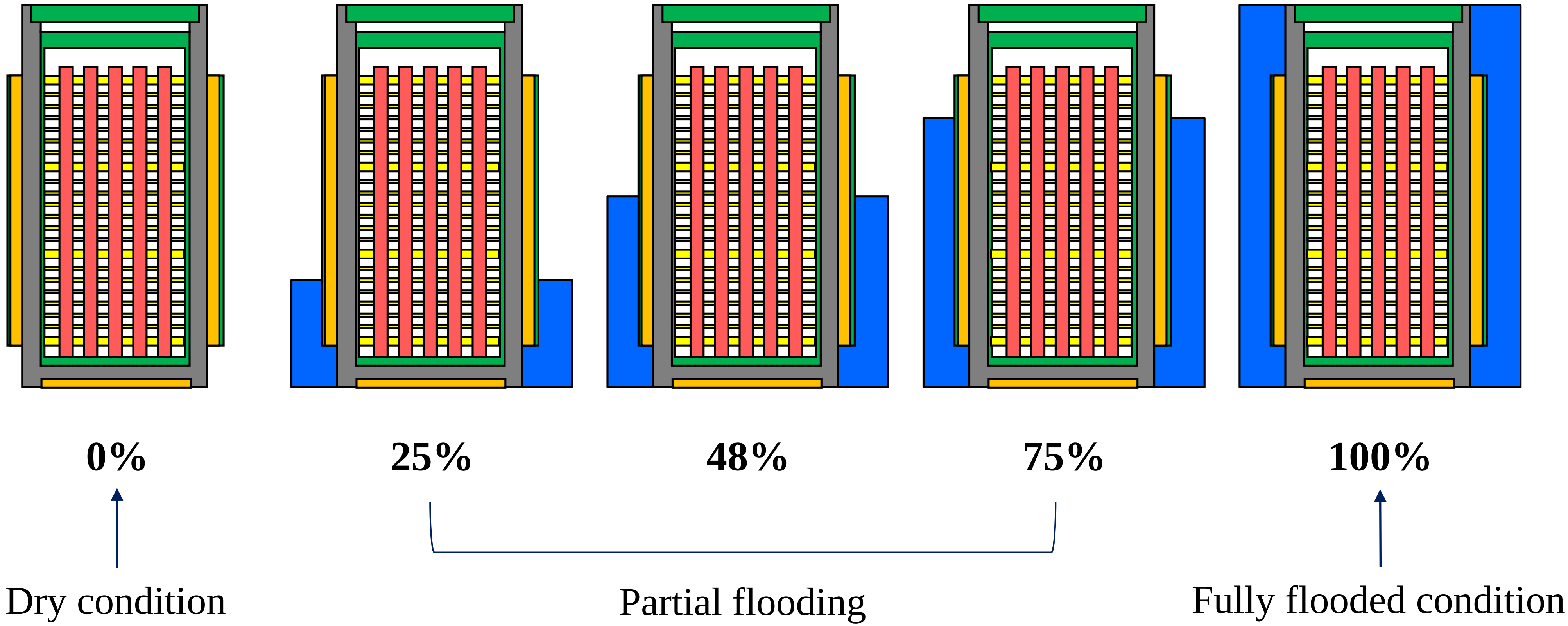
Off-normal condition

- The water condition could change according to outer environment state.

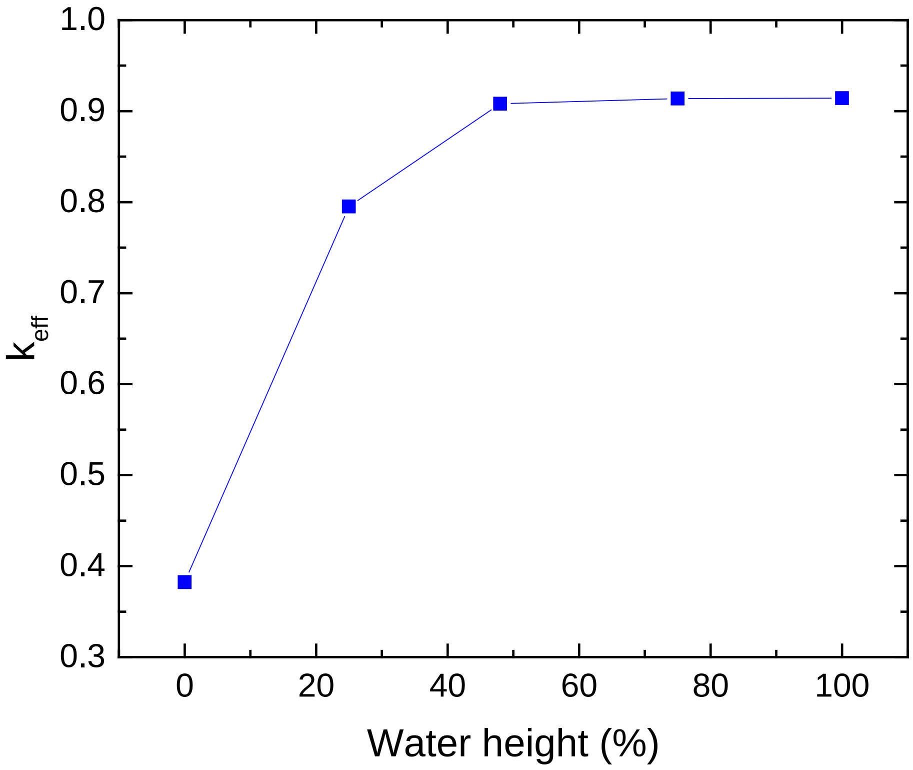
- The humidity inside the cask system and water smeared into the fuel rods should be considered.



□ Water height



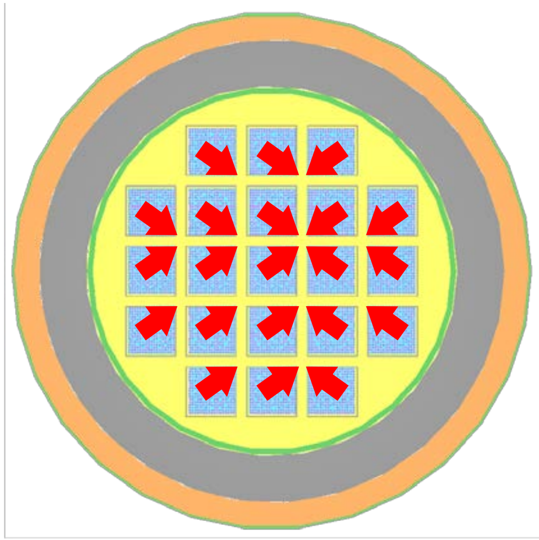
□ Water height

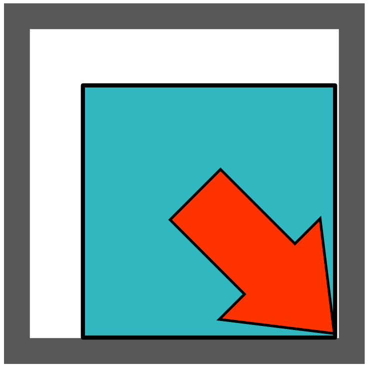


- Water filled with overall cask has the highest reactivity among partial and fully flooded conditions.

□ FA arrangement

- The FAs are leaned towards the center of the cask.
- The FAs are totally attached to the edge of the baskets.
- Calculations are performed under wet condition.

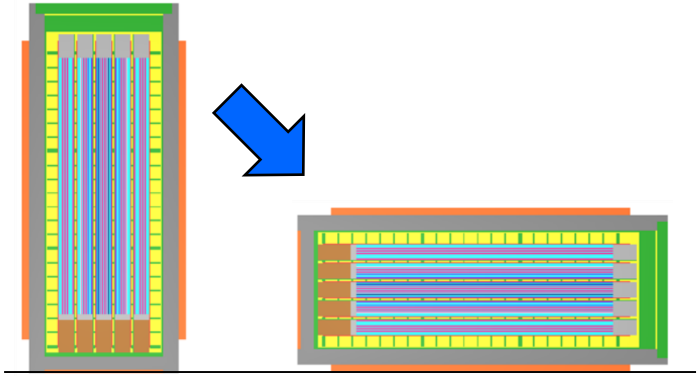




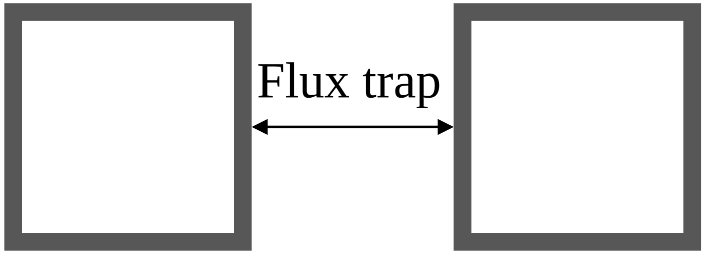
FA position	k_{eff}	SD
Center	0.91433	0.00020
Eccentric	0.91556	0.00021

3.3 Accident conditions

□ Flux trap reduction



- The flux trap could be diminished due to the accidents such as tip-over or drop.



Condition	k_{eff}	SD
Wet	0.91433	0.00020
Reduced flux trap	0.92297	0.00023

IV. Conclusions

4. Conclusions

- The optimum neutron absorber content for this study is selected as Gd 1 wt% and B 0.4 wt%.

- In the dry condition, the keff is lower than 0.4. However, the reactivity dramatically increases when the cask is flooded with water.

- The reactivity is the highest for the fully flooded condition.

- The effective multiplication factor shows the highest when the water density is 1 g/cm^3.

4. Conclusions

- In eccentric position of fuel assemblies, the keff increases about 0.01.

- When the cask tip-over, the flux trap could be decreased. If the flux trap reduced in maximum value, the reactivity increases about 864 pcm.

- From the calculations of normal, off-normal, and accident conditions, all the results satisfy the regulatory limit.

Thank you for your kind attention!