VALIDATION OF MVP CODE WITH HTC CRITICAL EXPERIMENTS

原子力規制委員会
Nuclear Regulation Authority

Shigeki Shiba

Regulatory Standard and Research Department,
Secretariat of Nuclear Regulation Authority (S/NRA/R)
shigeki_shiba@nsr.go.jp.

Contents

Background and Objectives

Background and Objectives

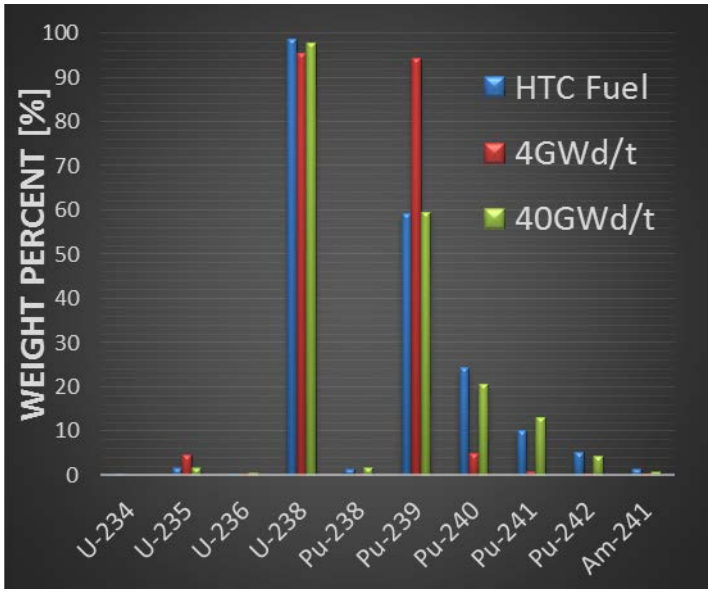
- ✓ Continuous Energy Monte Carlo code MVP-2.0 was developed by JAEA*.
- ✓ MVP-2.0 code was mainly validated against fresh fuel experiments.
- ✓ Appropriate validation of MVP-2.0 code is required to apply criticality safety analysis for systems with burned fuel.
- ✓ Applicability of MVP-2.0 code for burnup fuel was assessed using HTC experiment data.

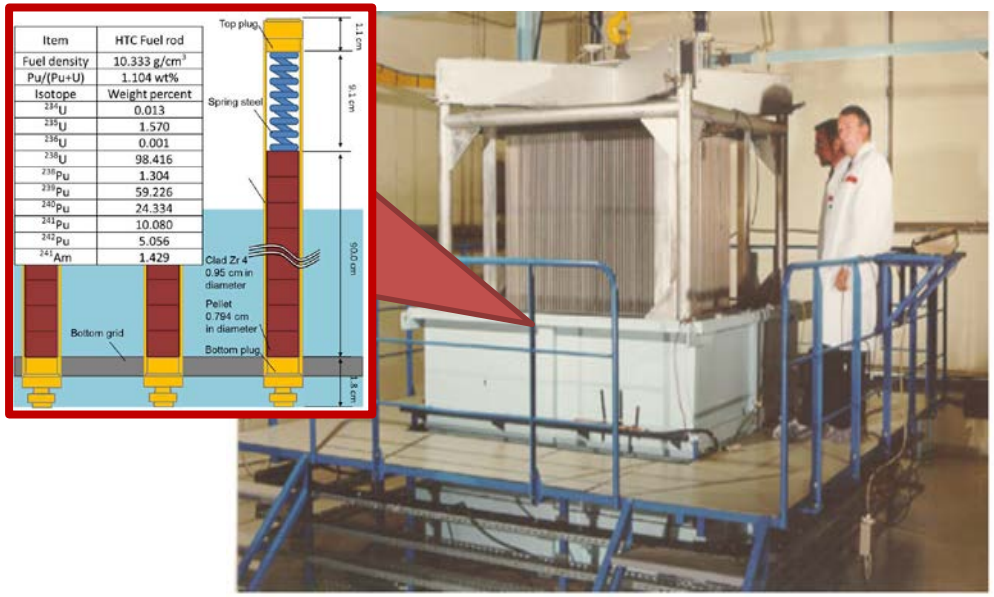
* Japan Atomic Energy Agency

HTC Experiments

HTC Experiments: Main features

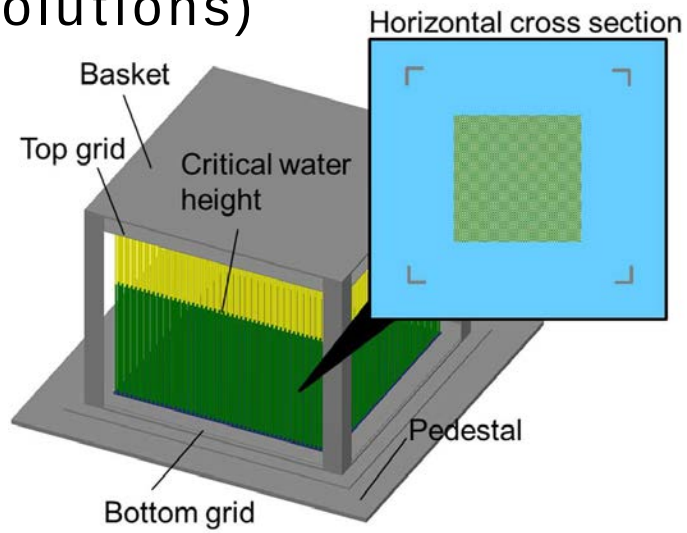
- Carried out during 1988-90 in the Valduc Critical Facilities of CEA, co-sponsored by IRSN and AREVA
- Newly manufactured 2500 pins that simulate the actinide concentration of an burned PWR fuel up to 37.5 GWd/t were used.



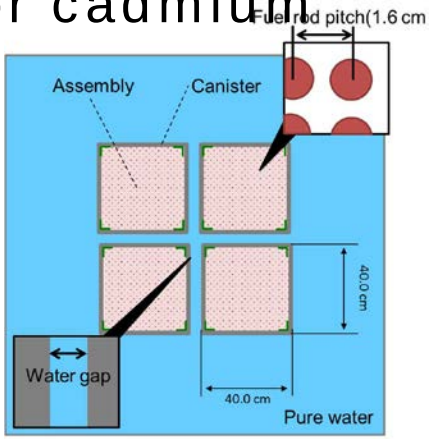


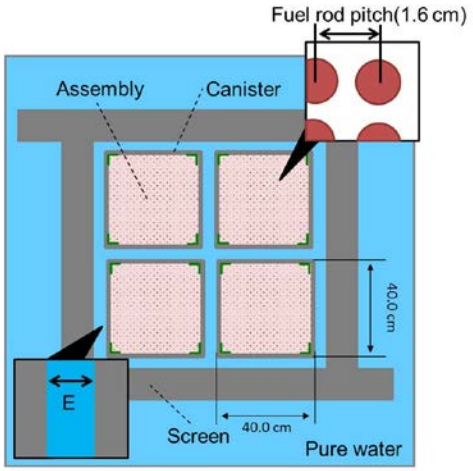
HTC Experiments: Configurations

- Phase 1 and 2: Fuel rods with a varied fuel rod pitch are loaded in three types of solutions (pure water, gadolinium or boron solutions)



- Phase 3: Four assemblies each of which is surrounded by borated steel, Boral, or cadmium side panels.





- Phase 4: Lead or steel screens are attached to the Phase 3 configuration

HTC Experiments: Principal parameters

Phase	Parameters	Number of cases
1	Rod Pitch (1.3-2.3 cm) Fuel Rod number	18
2	Rod Pitch (1.3-1.9 cm) Poison concentration (Gd, B) in solution Fuel rod number	41
3	Assembly gap Side panels (BSS, Boral, Cd)	26
4	Assembly gap Screen position Side Panels (BSS, Boral, Cd) Screens (Lead, Steel)	71
		156

Calculation code

MVP

+

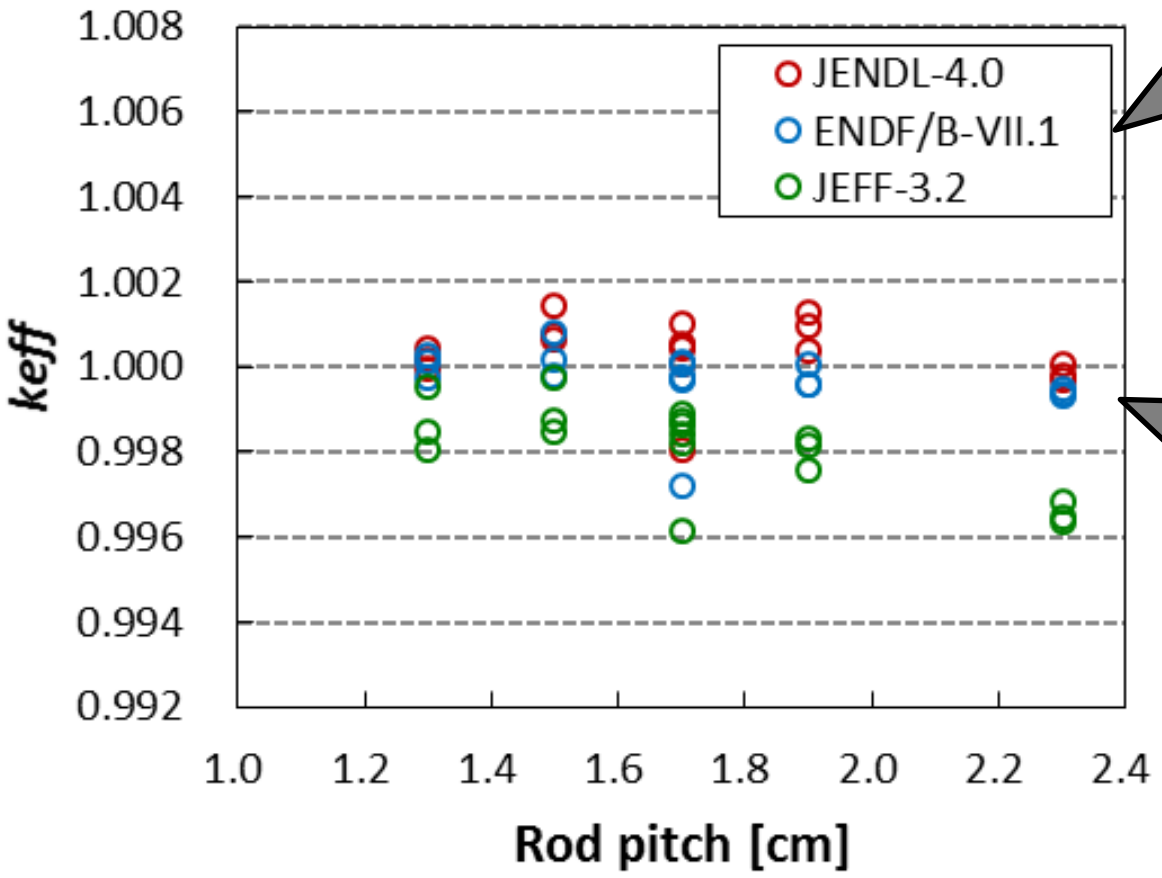
- JENDL-4.0
- ENDF/B-VII.1
- JEFF-3.2

HISTORY : 40,000
BATCH : 250
SKIP : 50

Validation Results

Validation results: Phase 1 (Pure water)

Nuclear data library	*keff*	Standard deviation
JENDL-4.0	1.0000	0.0007
ENDF/B-VII.1	0.9997	0.0007
JEFF-3.2	0.9981	0.0010

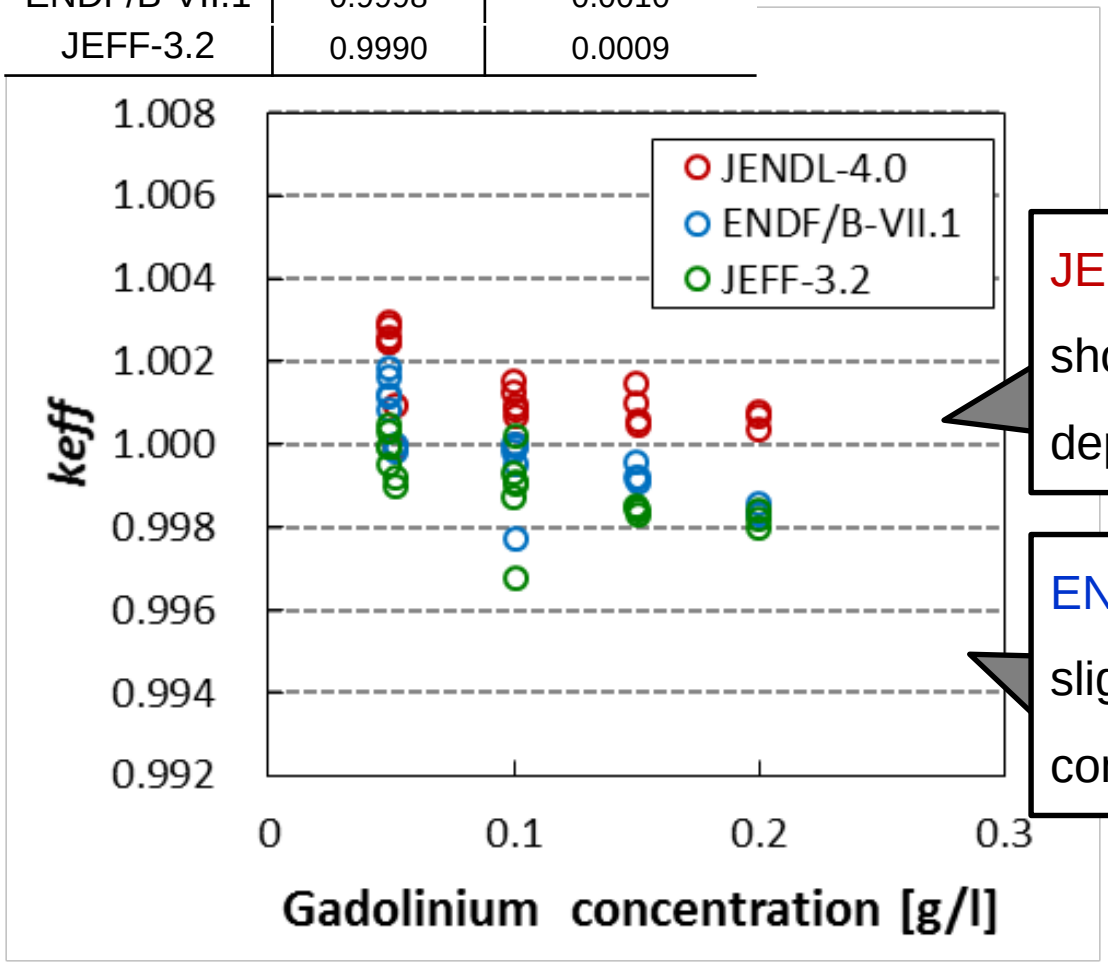


JENDL-4.0 and ENDF/B-7.1 show no fuel rod pitch dependence

JEFF-3.2 shows slight under-estimation when fuel rod pitch becomes wide

Validation results: Phase 2 Gadolinium Solution

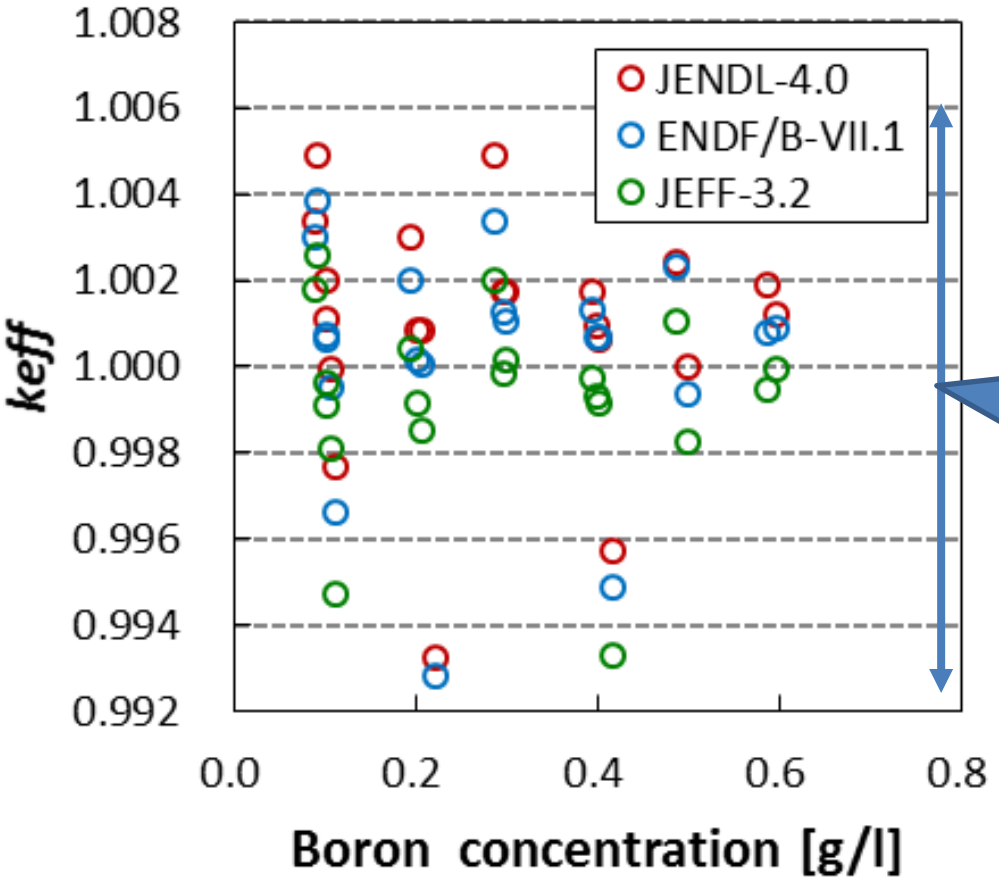
Nuclear data library	*keff*	Standard deviation
JENDL-4.0	1.0010	0.0009
ENDF/B-VII.1	0.9998	0.0010
JEFF-3.2	0.9990	0.0009



JENDL-4.0 shows no Gd concentration dependence

ENDF/B-7.1 and JEFF-3.2 show slight under-estimation when Gd concentration is high

Validation results: Phase 2 Boron Solution



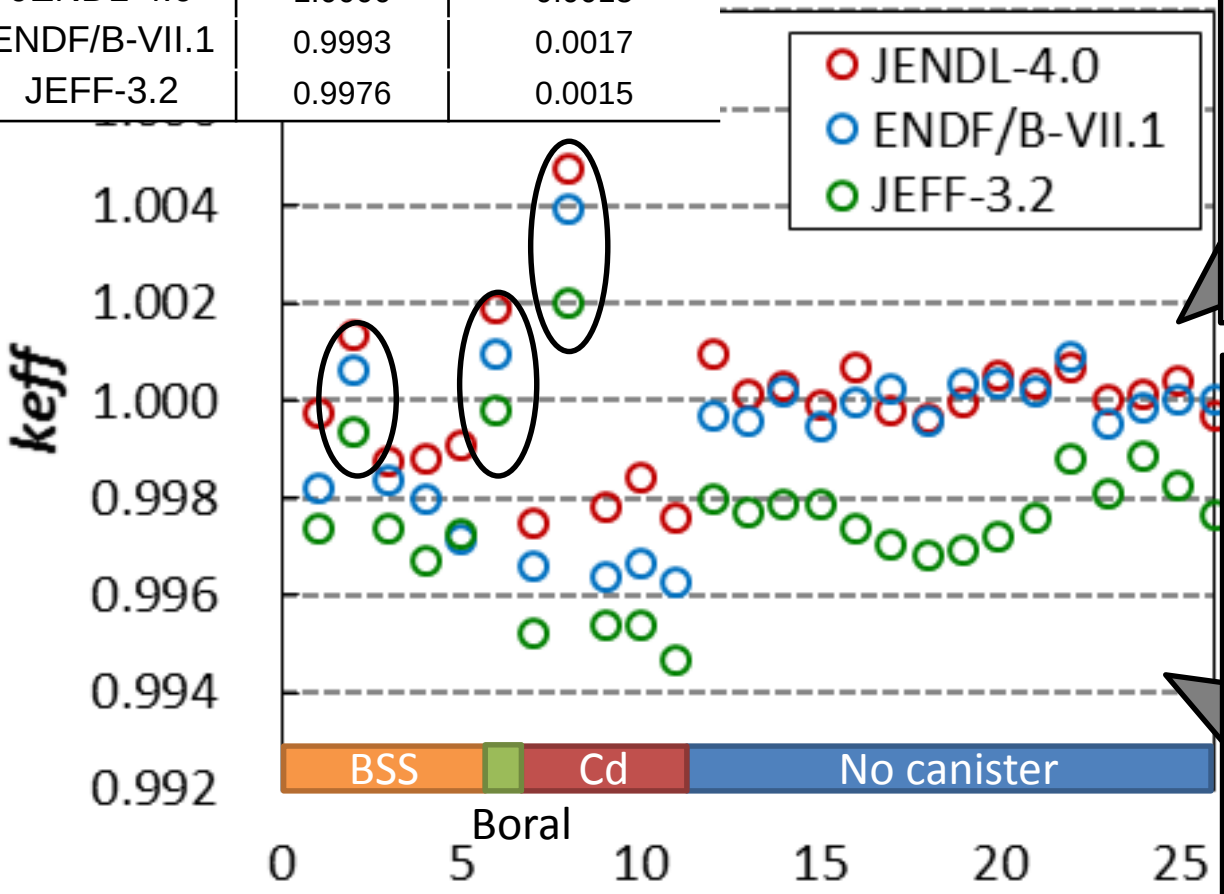
Nuclear data library	*keff*	Standard deviation
JENDL-4.0	1.0010	0.0027
ENDF/B-VII.1	1.0000	0.0027
JEFF-3.2	0.9989	0.0028

Experimental uncertainties, including the errors in controlling the boron concentration, are reported as large as tens hundreds of pcm in reactivity.

Hence, the large fluctuations observed in the Phase 2 experiments are presumably attributed to the experimental uncertainties.

Validation results: Phase 3

Nuclear data library	*keff*	Standard deviation
JENDL-4.0	1.0000	0.0015
ENDF/B-VII.1	0.9993	0.0017
JEFF-3.2	0.9976	0.0015



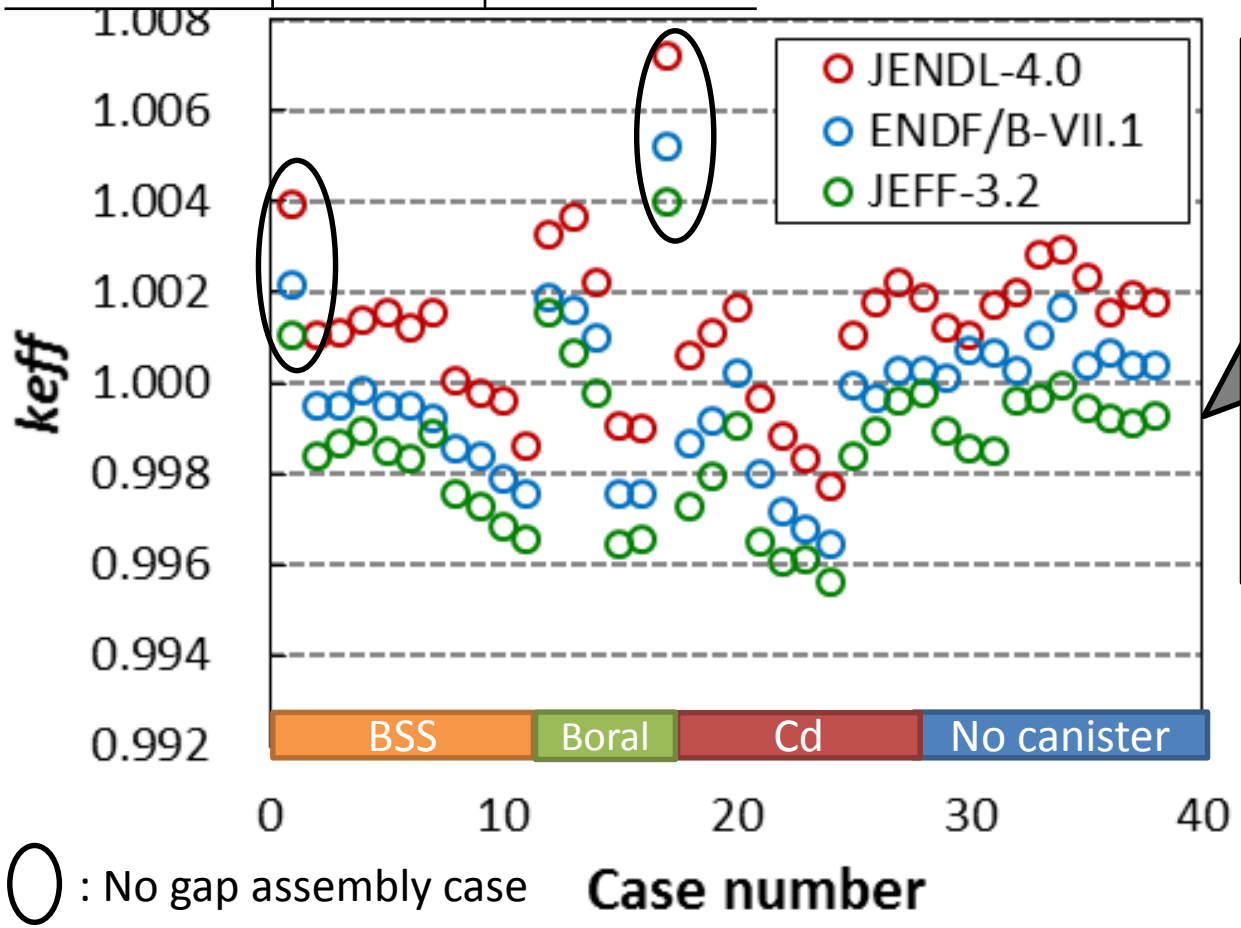
Relevant discrepancy in JENDL-4.0 and ENDF/B-7.1 is observed only for the cases with canisters.

JEFF-3.2 shows slight underestimation for the cases with/without neutron absorbers (Borated SS, BORAL, Cd)

○ : No gap assembly case

Validation results: Phase 4 Lead Screen

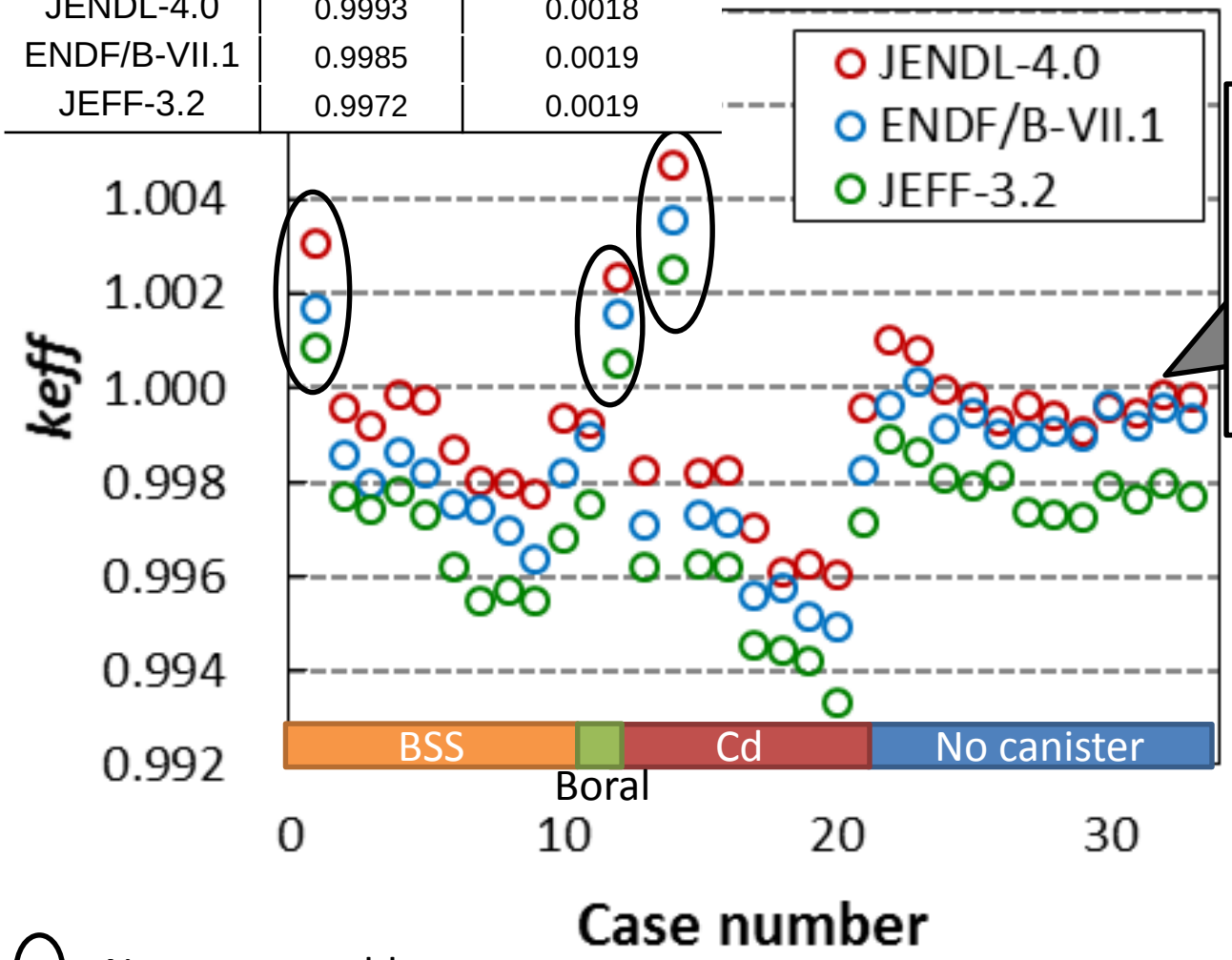
Nuclear data library	*keff*	Standard deviation
JENDL-4.0	1.0010	0.0018
ENDF/B-VII.1	0.9997	0.0017
JEFF-3.2	0.9986	0.0017



JENDL-4.0 shows over-estimation for no canister cases, which suggests that the error is originated from nuclear data of Pb.

Validation results: Phase 4 Steel Screen

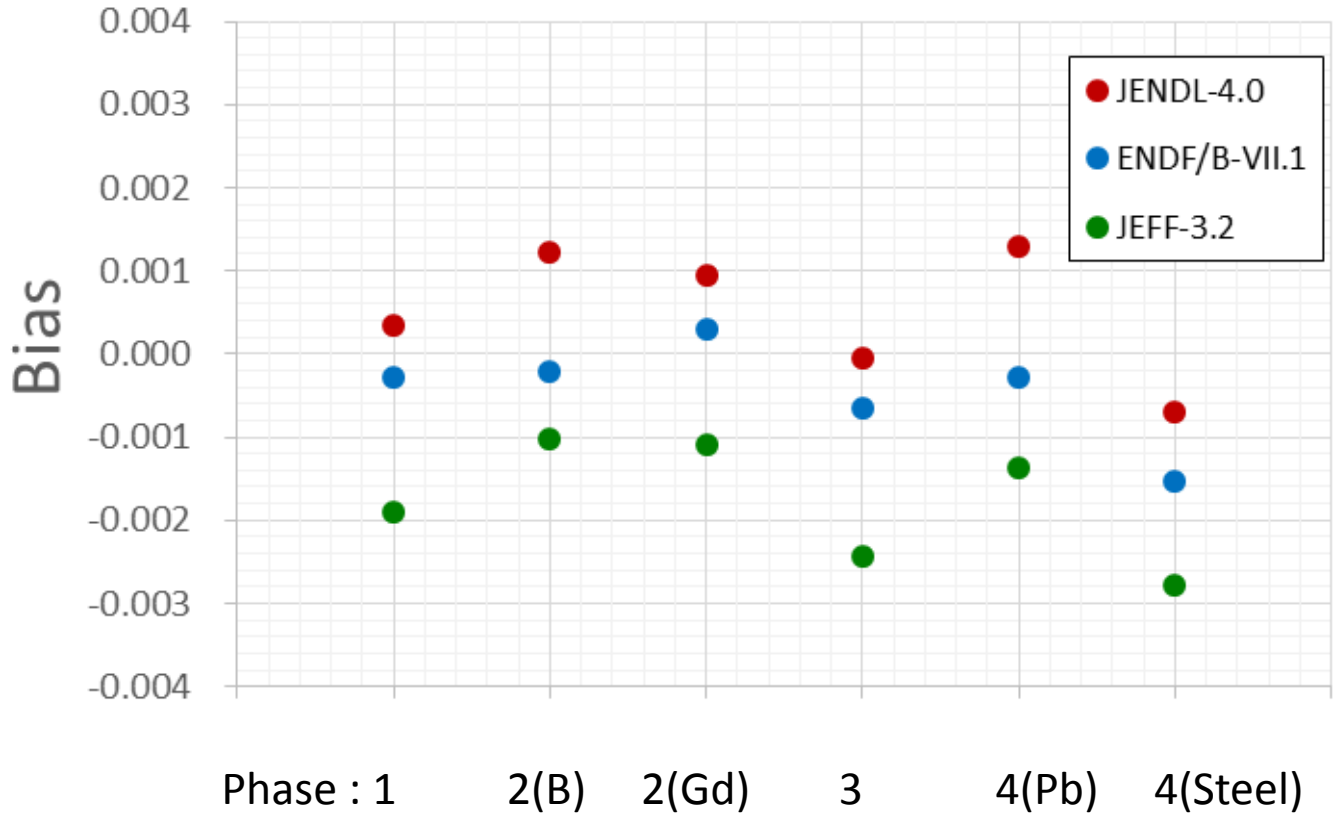
Nuclear data library	*keff*	Standard deviation
JENDL-4.0	0.9993	0.0018
ENDF/B-VII.1	0.9985	0.0019
JEFF-3.2	0.9972	0.0019



JENDL-4.0 and ENDF/B-7.1 show no over-estimation for SS screen cases without a canister.

○ : No gap assembly case

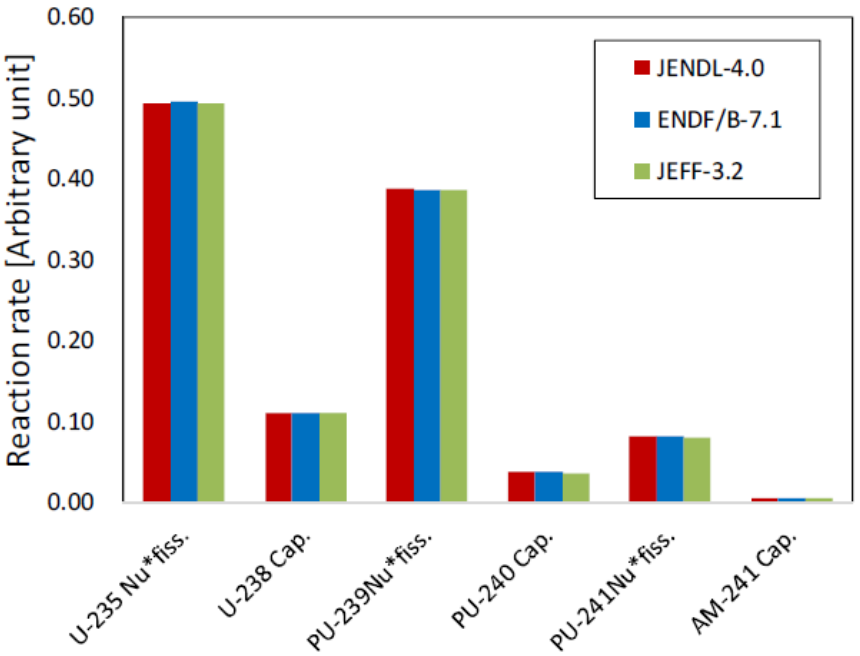
Validation results: Comparison between the Nuclear Data Libraries



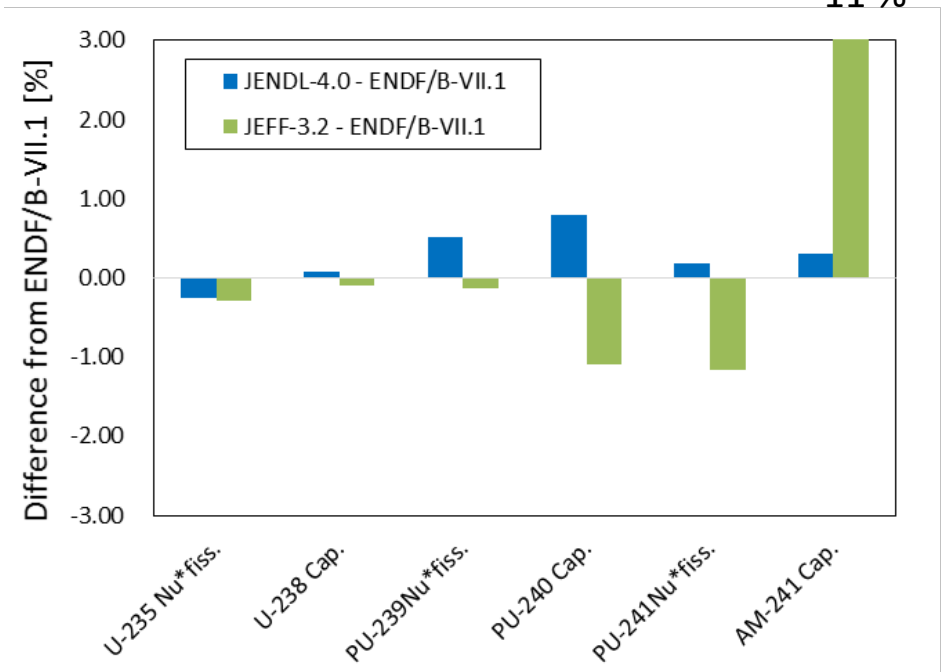
The biases of JENDL-4.0 showed a similar trend with those of ENDF/B-VII.1 and JEFF-3.2.

Discussions on Validation Results

Fission and Capture Reaction Rates



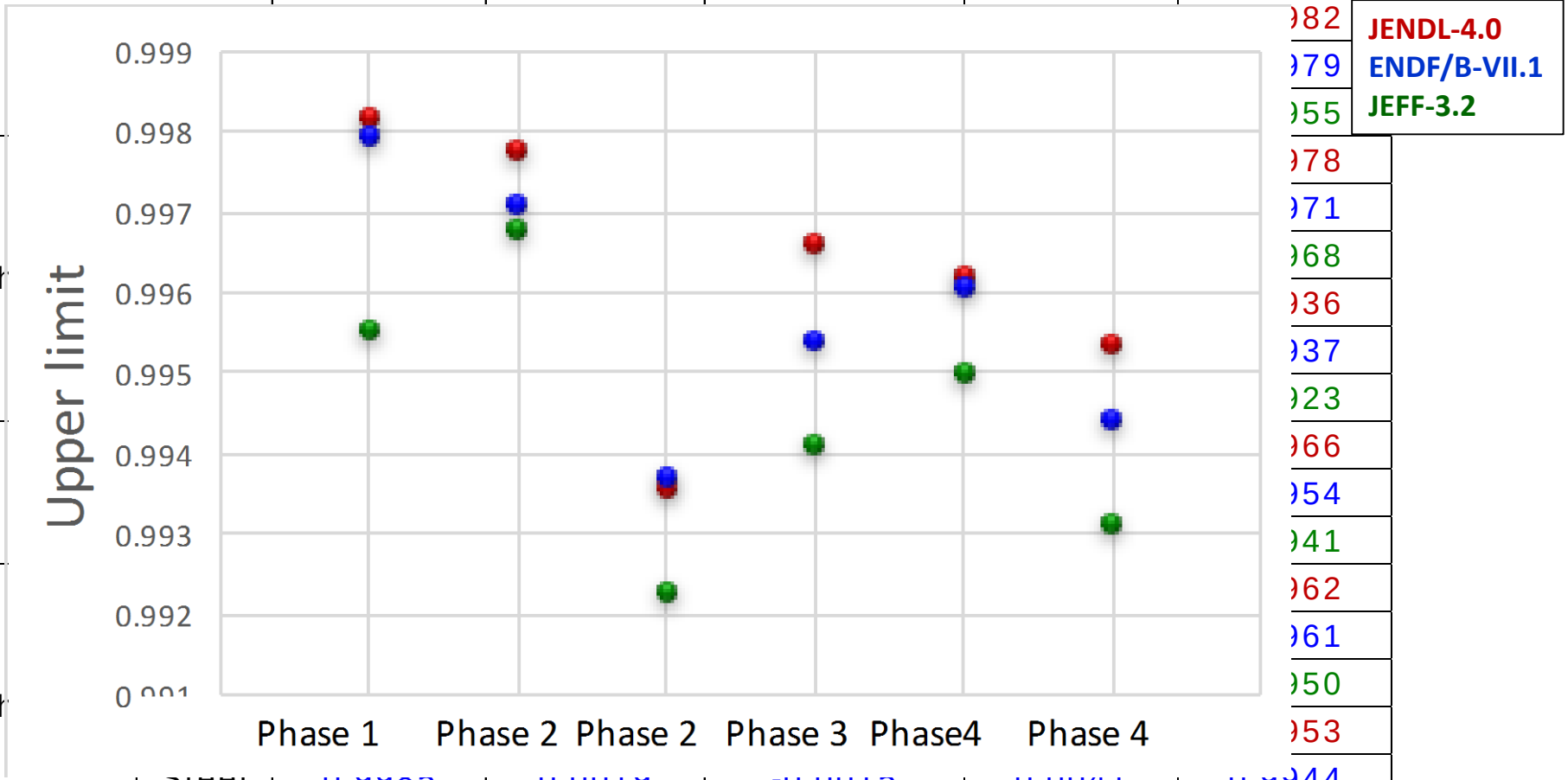
11 %



- ✓ In comparison with major reaction rates, JENDL-4.0 shows a 0.5% higher neutron production reaction rate in Pu-239 compared to ENDF/B-VII.
- ✓ JEFF- 3.2 shows smaller fission reaction rates for Pu-239, U-235, etc.

Summary of MVP calculations

Item	keff	Standard deviatioin	Bias	95%/95%	Upper limit
Ph					982
					979
					955
					978
					971
					968
					936
					937
					923
					966
					954
					941
Ph					962
					961
					950
					953
Steel	0.9985	0.0019	-0.0015	0.0041	0.9944
	0.9972	0.0019	-0.0028	0.0041	0.9931



- Positive biases were neglected to enhance the safety margin.
- MVP calculations resulted in small uncertainties over all Phases.

Summary

- ✓ MVP-2.0 code with major libraries has been validated using HTC experiment data.
- ✓ Applicability of MVP-2.0 code for actinide-only burnup fuel was confirmed and evaluated keff biases were within 300 pcm.
- ✓ We realized some differences in keff results between libraries through the validation task.
- ✓ Especially, keff results in JEFF-3.2 were underestimated.
- ✓ The differences in keff results are caused by differences in the fission reaction rate, etc.