IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

THE EFFECT OF NEUTRON REFLECTION CONSIDERING A FIXED THICKNESS OF WATER FOLLOWING SEVERAL MATERIALS

M. MILIN and G. CAPLIN

Institute for Radiological Protection
and Nuclear Safety (IRSN)
France

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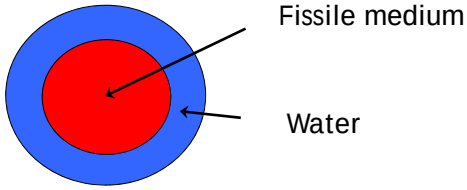
Content

Introduction

Criticality safety practice usually takes into account a fixed thickness of water



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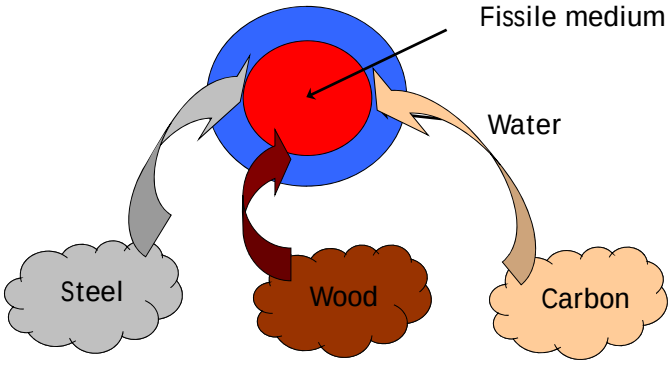
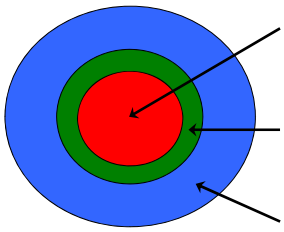


What is the impact on reactivity of reflection by different materials?

Model / Aim of this paper

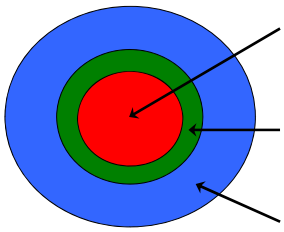


Fissile medium

Reflector material (wood, steel, carbon…)

Water

Model / Aim of this paper



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↗ **Reactivity impact of material (thickness or mass)**

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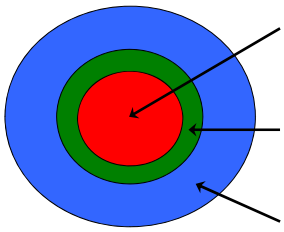

Fissile medium

Reflector material (wood, steel, carbon…) ?

Water ?

- **Reactivity impact of material (thickness or mass)**
- **Effect of the additional thickness of water**

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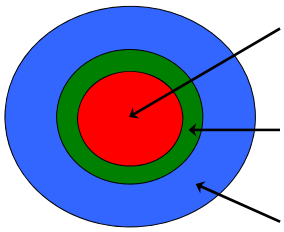


Fissile medium ?

Reflector material (wood, steel, carbon…) ?

Water ?

- **Reactivity impact of material (thickness or mass)**
- **Effect of the additional thickness of water**
- **Comparison of reflection versus neutron spectrum**

Fissile media / Calculations code

This study is performed only with ^{239}Pu in different forms:

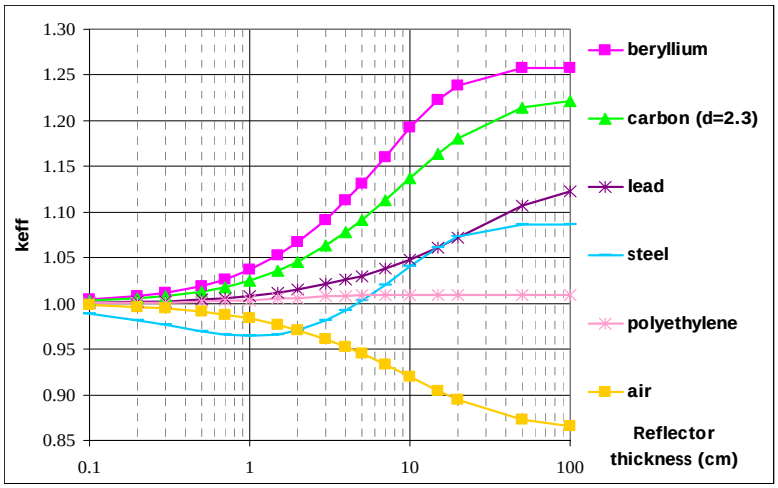
- Pu metal with an optimal moderation by water (called optimal_mod),
- PuO_2 of density 3.5 and 6 % weight of water (called powder_wet),
- PuO_2 of density 4 without any moderation (called powder_dry),
- Pu metal of density 11.2 (called met_d11.2),
- Pu metal of density 19.86 (called met_d19.86).

Fissile media	optimal_mod	powder_wet	powder_dry	met_d11.2	met_d19.86
EALF (eV) for full water reflection	0.54	844	6081	40752	102190

Calculations are performed using APOLLO2-Sn in 1D geometry, which is one of the standard routes of CRISTAL V1 package.

Content

Results for a fixed thickness of 20 cm of water



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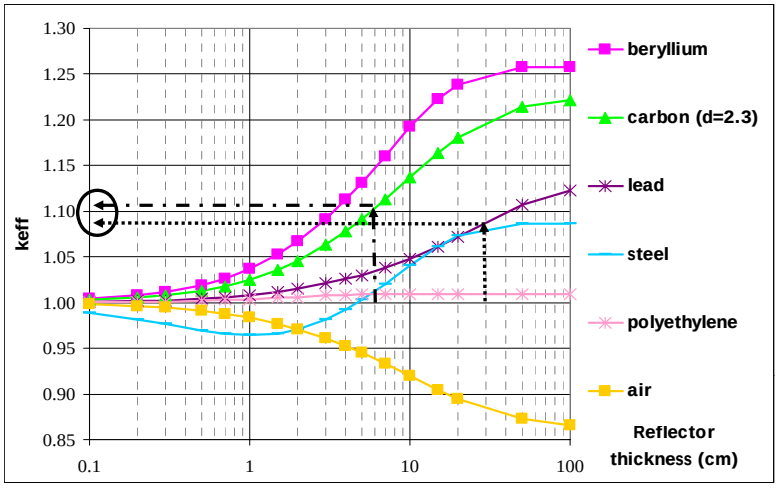
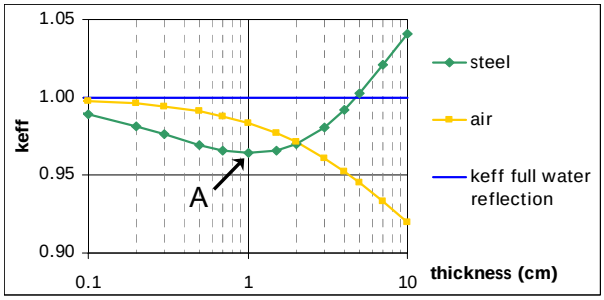


- **This type of figure is an easy and quick method to compare reflection effect for different materials and different thicknesses**

Notable thicknesses for absorbing materials



A : the absorbing effect is highest

Fissile Media	Thickness (cm)	Steel	Copper	Titanium	PVC
optimal_mod	A	1	1	2	3
	B	2	2.2	5	9
	C	4.7	5.4	50	-
powder_wet	A	2	1.7	4	3
	B	2.3	2.1	5	8.3
	C	6.1	5.5	35	-
met_d19.86	A	2	1.8	7	4
	B	-	-	3.7	4.3
	C	7.4	4.2	-	-

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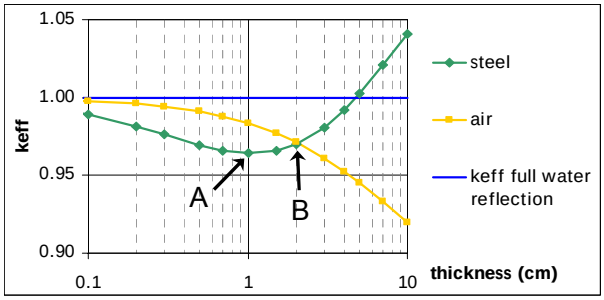

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B : the reactivity with the material is higher than air

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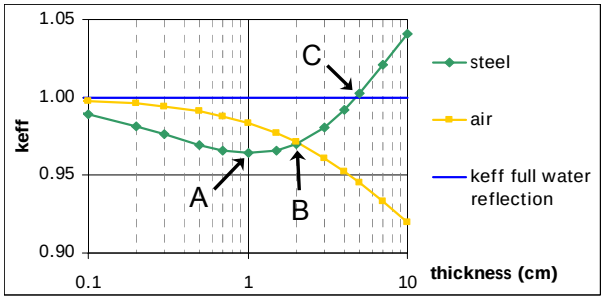

A : the absorbing effect is highest

B : the reactivity with the material is higher than air

C : reflection with the material is higher than reflection with water only

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Results with a variation of material mass (1/2)

Could the results for a variation of material thickness be used to compare reflection versus a variation of material mass?

Results with a variation of material mass (2/2)

Derive method: calculations considering a variation of material thickness
Accurate method: calculations considering a variation of material mass

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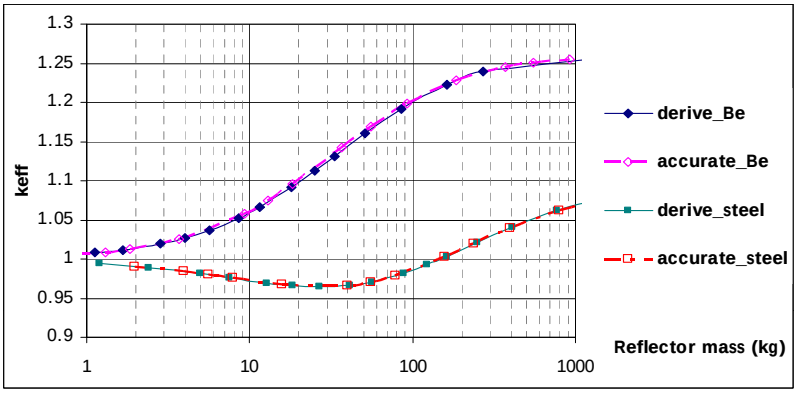
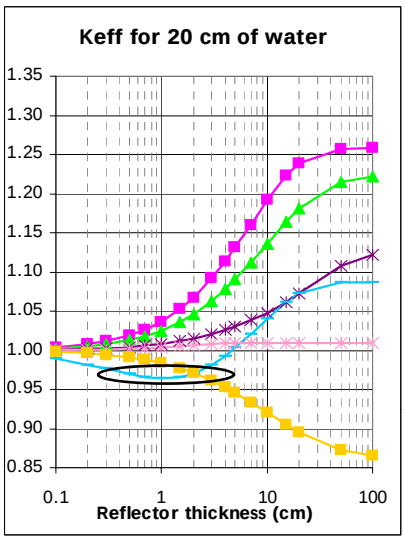
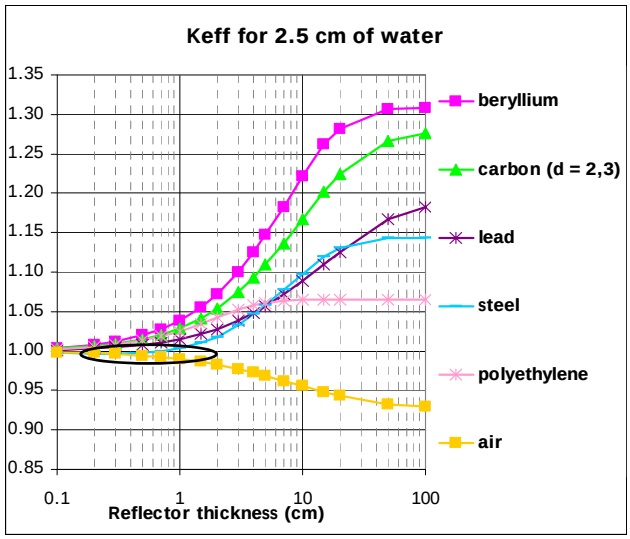


- **The differences on reactivity are very small (less than 0.5%)**
- **The use of the derive method is acceptable for quick comparison**

Content

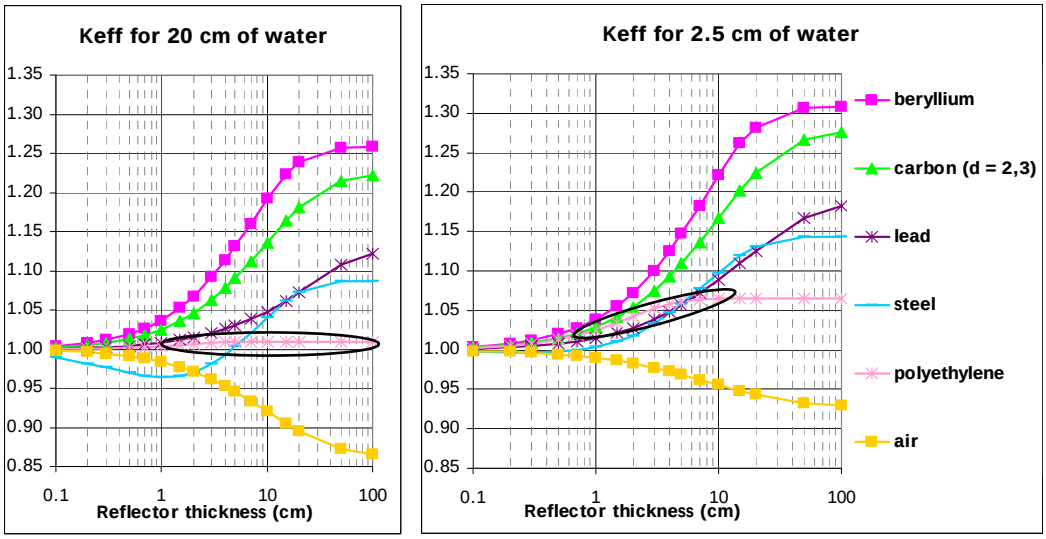
Impact on reactivity of the fixed thickness of water





The higher the thickness of water is, the higher the absorbing effect is

Impact on reactivity of the fixed thickness of water

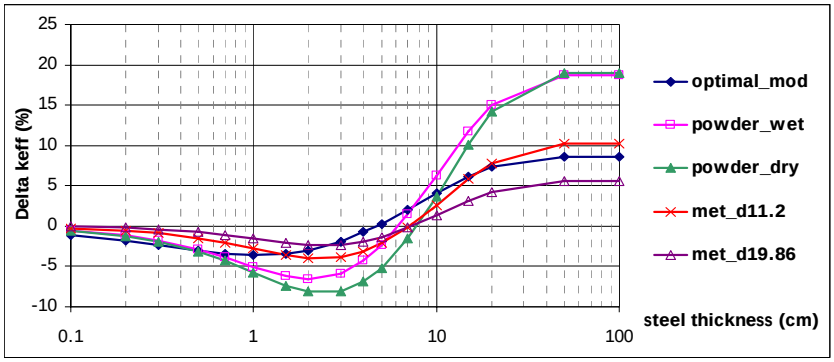


For thin thickness of material, the hierarchy of reflector depends on the additional thickness of water

Content

1st reflection comparison versus spectrum

$$Delta\ keff = Keff_{studied\ material} - Keff_{additional\ thickness\ of\ water\ (20\ cm)}$$



- Neutron absorption is more important for epithermal spectra than thermal spectra
- For full thickness, reflection by steel is twice more important for epithermal spectra than thermal and fast spectra

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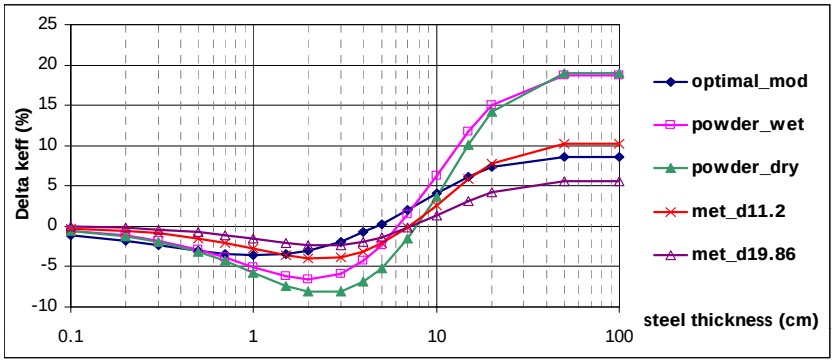

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Impact on reactivity of full water reflection

Fissile media	optimal_mod	powder_wet	powder_dry	met_d11.2	met_d19.86
Impact (%)	13.9	34.7	34.4	22.7	15.7

- This impact explains the two previous remarks.
- So, a normalisation is useful to compare reflection versus neutron spectrum

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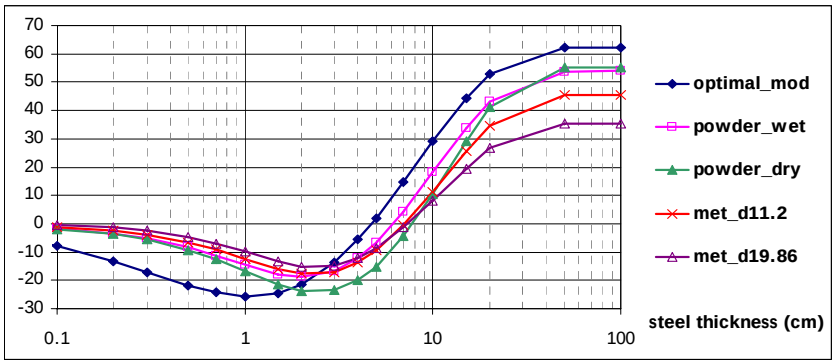
Normalisation formula:

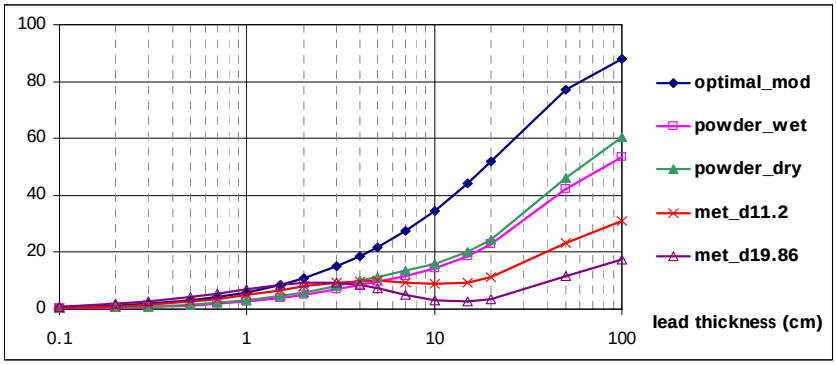
$$100 \times \frac{Keff_{\,studied\ \ material} - Keff_{\,additional\ \ thickness\ \ of\ \ water\ (20\ cm)}}{Keff_{\,full\ \ water\ \ reflection} - Keff_{\,bare}}$$

Application of this normalization for steel



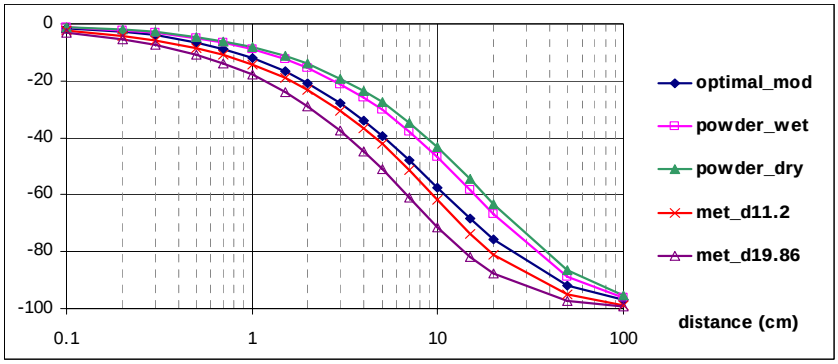
- **The conclusions from this figure are more in accordance to the expected.**
- **The notable thicknesses are smaller for thermal spectra than fast or epithermal spectra.**

Application of this normalization for lead



- **For thin thicknesses, the impact on reactivity is similar whatever the neutron spectrum is.**
- **For large thicknesses, reflection impact is higher for thermal spectra than fast spectra.**

Results for distance between fissile media and water



- For a similar spectrum, the smaller the fissile medium radius is, the higher the decrease on reactivity is.
- For an identical fissile medium radius, the more thermal the neutron spectrum is, the higher the decrease on reactivity is.

Conclusion

- The additional thickness of water has an impact on reflection by materials
  - The classification of reflector depends on this thickness of water
  - The absorbing property of certain materials appears
- Results for a variation of material thickness can be used for the study of a variation of material mass
- Comparison of reflector materials versus neutron spectrum is possible with a simple normalization
- This study presents methods which can be used by criticality specialists to compare quickly and easily the reflection versus material thickness or mass and neutron spectrum

Thank you for your attention

Question?