Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Istituto Nazionale di Fisica Nucleare
Sezione di Bologna

Proposal for a new evaluation of the Erbium capture cross sections

ENEA, INFN and UNIBO
(*n_TOF collaboration*)

A. Guglielmelli, F. Rocchi, C. Massimi, D.M. Castelluccio

n_TOF Italian Meeting, 05/07/2021

Motivations (Erbia vs Gadolinia)

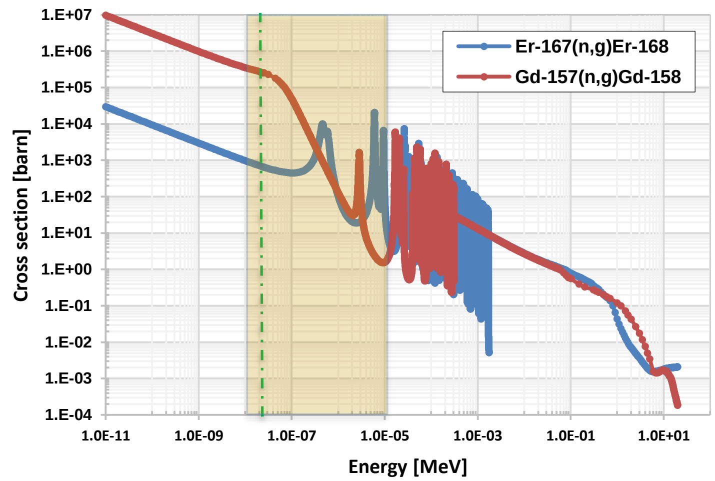
- ## Scientific aspects:

– Lower thermal absorption cross sections ***(Er: 162 b; Gd: 2.5E+05 b)*** **not downgrade the power distribution**;

– More negative temperature feedback coefficient ***(α=δk/δT)*** **higher reactor core safety**;

– Higher and more energy extensive resonance integrals **better control of start-up and accidental transient phases**;

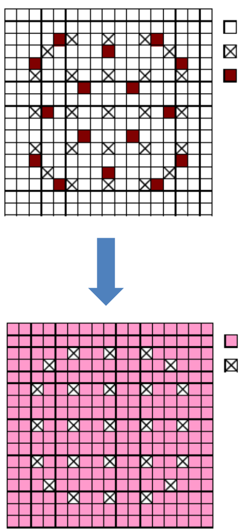
– Reduction of 239Pu in a EoL fuel core inventory **improvement of the non-proliferation actions.**

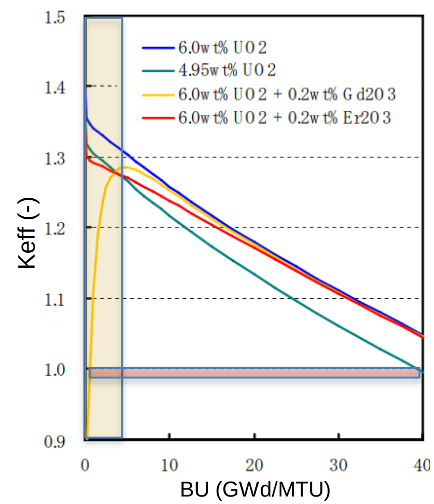


- ## Nuclear safety and economical aspects:

– Er-Super High Burnup fuel concept (BU>70 GWd/MTU, erbia>0.2 wt%, U-235> 5 wt%) was adopted in some exp. campaigns:

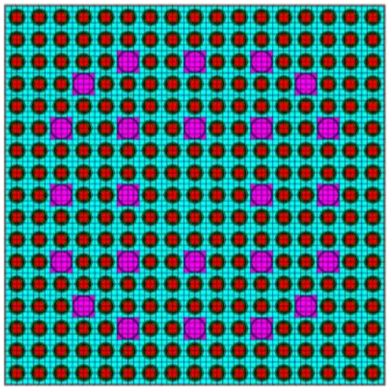
- Low content of Erbia is add into all UO2 (>5 wt%) powder just after the re-conversion process;
- Fuel enrichment is greater than 5 wt% but at BOL is equivalent to 5 wt%;
- Higher enriched fuel (HEU, enr > 5 wt%) can be handle within the existing fabrication facilities with **an improvement of the criticality safety** and a **global reduction of in-core the fuel cost**





S&U Analysis & Available data

• S&U studies (Er-SHB FA):



Er$_i$(n,g) are one of the major contributors to the uncertainty after U reactions.

Er-167	dk/k (-)	dk(pcm)
	9.25E-04	123(17.8%)

Er-166	dk/k (-)	dk(pcm)
	1.72E-04	23(3.3%)

Er-168	dk/k (-)	dk(pcm)
	8.48E-05	11(1.6%)

Er-170	dk/k (-)	dk(pcm)
	7.01E-05	9 (1.3%)

The overall uncertainty due to Er$_i$(n,g) is equal to **126 pcm** roughly **18.2%** of the overall Xs(n,j) uncertainty contribute (i.e., **688 pcm**).

• Evaluated data (ENDF/B-VII.1):

Er-166	
eV	%
0.5	**7.25**

Er-167	
eV	%
0.5	**2.35**

Er-168	
eV	%
0.5	**12.00**

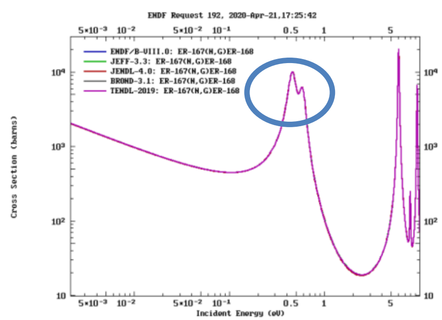
Er-170	
eV	%
0.5	**15.28**

Only one evaluated point in the Xs high sensitivity region, namely **between 0.5 and 5 keV!**

• Exp. data (EXFOR, Er-167):

Age	Data (thrm. point)	Data Error	Data Error	Dev from average
[year]	[b]	[b]	[%]	[%]
1958	620.0	125	20.2	-6.0
1967	699.0	20	2.9	5.9
1968	658.0	30	4.6	-0.3
1998	644.4	2.4	0.4	-2.3
1958-1998	655.4	STD: 33.1 b	**STD: 5.1%**	-

Data with values below of 10% from the average have a **STD major than 5%!**



Only one resonance data used for several Er-167(n,g) evaluation!

• Resonance parameter (Er-167):

Reference	Γγ (0.46) (meV)	Unc (meV)	gΓn (0.58) (meV)	Unc (meV)
T. Wang et al.	94.72	0.94	0.1068	0.002
Danon et al.	87.12	0.16	0.1082	0.0004
Mughabghab	87.12	0.16	0.1082	0.0005
Landolt-Bornstein	88	1	0.12	0.01
ENDF/B-VII.0-1	87.12	-	0.1082	-
Average	88.82		0.110	
STD [%]	**3.74**		**4.96**	

ICSBEP 2019 database

- Erbium isotopes is included in the International Criticality Safety Benchmark Evaluation Project (ICSBEP, 2019) in solid form as adsobers whitin the fuel or the control rods.

- Erbia in solid form is present only in three facilities of the two ICSBEP database:

✓ **DICE**:

1. LEU-MET-THERM-005 (Experimental facility to support the Er-SHB project);
2. IEU-COMP-THERM-013 (TRIGA, Mark II research reactor).

✓ **IDAT**:

1. CROCUS-LWR-RESR-001(Zero-power reactor, critical research facility).

LEU-MET-THERM-005 (2012)

- The KUCA B-core is a multipurpose, reconfigurable array assembled using a number of fuel elements that can be specifically tailored to match experimental goals;
- The LMT-T-005 experiments were conducted in support of the Er-SHB fuel concept development program.

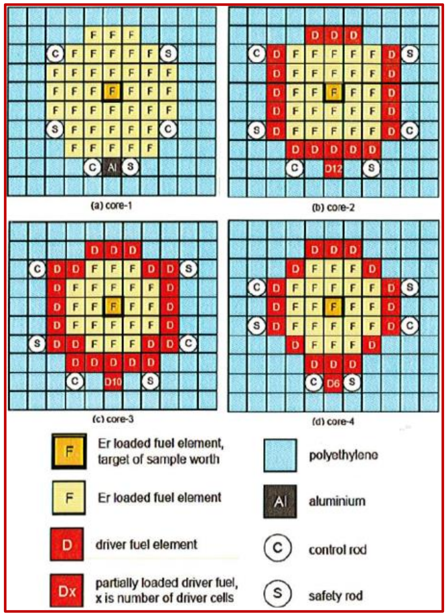


Table 1-1. Comparison of Core Parameters.

Case	Average Enrichment (wt. %)	Erbia Content (wt. %) Erbia/U-total	$H/^{235}U$	Outline
0	5.4	-	277	Reference core without erbia
1	5.4	0.3	277	Homogeneously erbia-loaded core very soft spectrum
2	5.4	0.3	91	Zone-type core with driver to simulate PWR spectrum
3	9.6	0.6	48	Zone-type core with driver Harder spectrum
4	9.6	1.12	148	Zone-type core with driver Higher erbia content

Figure 1-2. KUCA B Core (Top View).

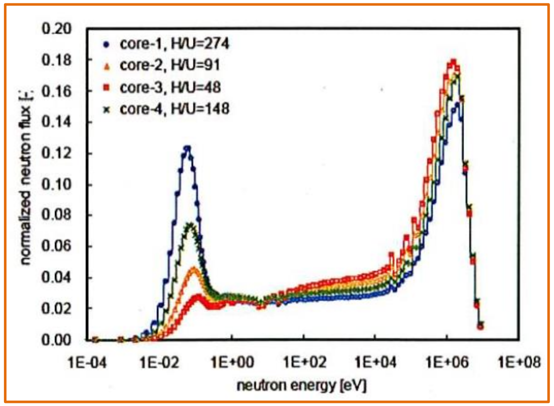
Table 3-24. Experimental and Benchmark K_{eff}.

Core	Experimental $k_{eff} \pm 1\sigma$	Simplification Bias	Benchmark $k_{eff} \pm 1\sigma$
0	1.0000 ± 0.0006	-0.0012 ± 0.0001	0.9988 ± 0.0006
1	1.0000 ± 0.0005	-0.0012 ± 0.0001	0.9988 ± 0.0005
2	1.0000 ± 0.0008	-0.0012 ± 0.0001	0.9988 ± 0.0008
3	1.0000 ± 0.0010	-0.0011 ± 0.0001	0.9989 ± 0.0010
4	1.0000 ± 0.0006	-0.0007 ± 0.0001	0.9993 ± 0.0006

LEU-MET-THERM-005

Table 4-2. Comparison of Sample Calculations using MCNP5 and Various Neutron Cross Section Libraries.

Case No.	Core	Code (Library)	Calculated $k_{eff} \pm 1\sigma$	Benchmark keff ± 1σ	(C-E)/E (%)
1	0	MCNP5 (JEFF-3.1)	1.0026 ± 0.0001	0.9988 ± 0.0006	0.38
2	1		1.0035 ± 0.0001	0.9988 ± 0.0005	0.47
3	2		1.0016 ± 0.0001	0.9988 ± 0.0008	0.28
4	3		1.0027 ± 0.0001	0.9989 ± 0.0009	0.38
5	4		1.0057 ± 0.0001	0.9993 ± 0.0006	0.64
1	0	MCNP5 (ENDF/B-VII.0)	1.0015 ± 0.0001	0.9988 ± 0.0006	0.27
2	1		1.0021 ± 0.0001	0.9988 ± 0.0005	0.33
3	2		1.0007 ± 0.0001	0.9988 ± 0.0008	0.19
4	3		1.0020 ± 0.0001	0.9989 ± 0.0009	0.33
5	4		1.0047 ± 0.0001	0.9993 ± 0.0006	0.54
1	0	MCNP5 (JENDL-3.3)	1.0003 ± 0.0001	0.9988 ± 0.0006	0.15
2	1		1.0009 ± 0.0001	0.9988 ± 0.0005	0.21
3	2		0.9990 ± 0.0001	0.9988 ± 0.0008	0.02
4	3		1.0007 ± 0.0001	0.9989 ± 0.0009	0.18
5	4		1.0036 ± 0.0001	0.9993 ± 0.0006	0.43
1	0	MCNP5 (ENDF/B-VI.8)	0.9996 ± 0.0001	0.9988 ± 0.0006	0.08
2	1		0.9999 ± 0.0001	0.9988 ± 0.0005	0.11
3	2		0.9976 ± 0.0001	0.9988 ± 0.0008	-0.12
4	3		0.9998 ± 0.0001	0.9989 ± 0.0009	0.09
5	4		1.0027 ± 0.0001	0.9993 ± 0.0006	0.34
1	0	MCNP5 (ENDF/B-V.2)	0.9986 ± 0.0001	0.9988 ± 0.0006	-0.03
2	1		0.9992 ± 0.0001	0.9988 ± 0.0005	0.04
3	2		0.9965 ± 0.0001	0.9988 ± 0.0008	-0.23
4	3		0.9987 ± 0.0001	0.9989 ± 0.0009	-0.02
5	4		1.0014 ± 0.0001	0.9993 ± 0.0006	0.21



CASE	Sensitivity Er-167 (n,γ)
2	2.24E-02
3	2.20E-02
4	2.25E-02
5	4.32E-02

CASE	CORE	Enr.	Erbia	H/U238	Kben	Kcal	ΔK	Δ(Δk)
(-)	(-)	(wt%)	(wt%)	(-)	(-)	(-)	(pcm)	
1	0	5.4	0	277	0.9988	1.0015	270	-
2	1	5.4	0.3	277	0.9988	1.0021	330	60
3	2	5.4	0.3	91	0.9988	1.0007	190	-
4	3	9.6	0.6	48	0.9989	1.0020	310	120
5	4	9.6	1.12	148	0.9993	1.0047	540	230

1-2

3-4

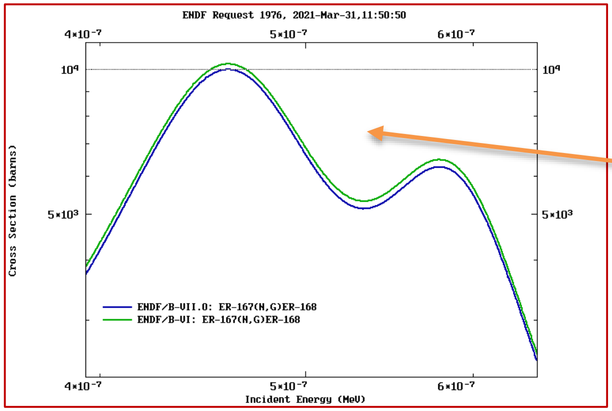
4-5

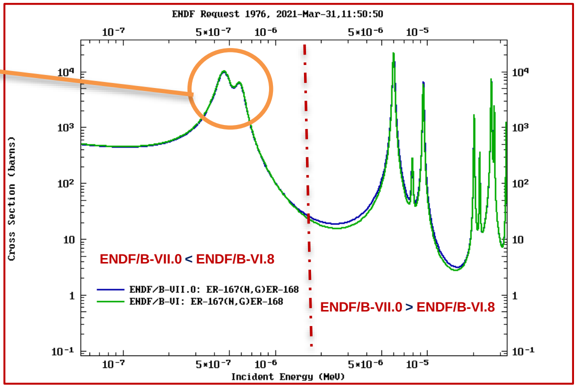
Note: Criticality difference between calculated and experimental values **Δ(ΔK)** increase as Erbia content increase.

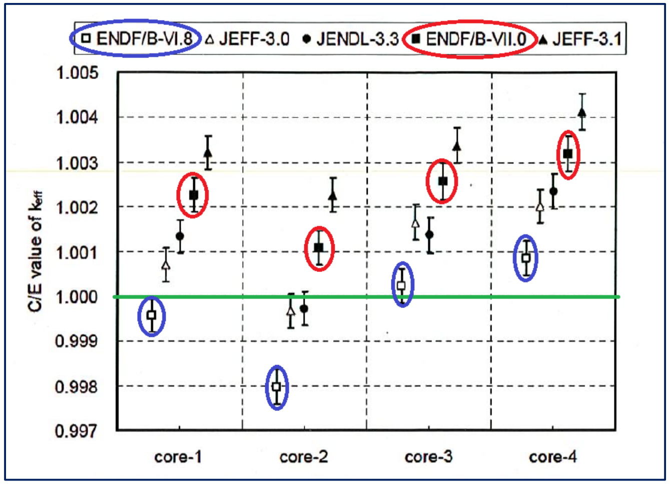
LEU-MET-THERM-005 (k_{eff} cal. vs exp.)

- Criticality analyses on the KUCA 4 core configurations were performed by means of MVP MC code using several nuclear data libraries (JENDL-3.3, ENDF/B-VI.8, JEFF-3.0, ENDF/B-VII.0) **[9].**

- The results were reported as C/E value of keff. The error bars represent the 3σ statistical uncertainty;
- ENDF/B-VII.0 and ENDF/B-VI.8 trend is to overestimate and underestimate, respectively;
- It can be supposed that the discrepancies are partially caused from differences between ENDF/B-VI.8 and ENDB/B-VII.0 $Er^{167}(n,\gamma)$;
- $Er^{167}(n,\gamma)$ of ENDF/B-VII.1 ENDF/B-VIII.0 equal to ENDF/B-VII.0.







$$\Delta\left(\frac{C}{E}\right) = 220 \div 300\ pcm$$

LEU-MET-THERM-005 (Xs unc. eval.)

$$if\ (H/U|_j = H/U|_{j+1}) \quad and \quad (C_{Er,j} \neq C_{Er,j+1}) \quad \Longrightarrow \quad \Delta(\Delta \boldsymbol{k}) = (\Delta \boldsymbol{k}_{j+1} - \Delta \boldsymbol{k}_j)$$

$$if\ \left(H/U\Big|_j \neq H/U\Big|_{j+1}\right) \quad and/or \quad (C_{Er,j} \neq C_{Er,j+1}) \quad \Longrightarrow \quad \Delta(\Delta \boldsymbol{k}) = \left(\frac{\boldsymbol{S}_j}{\boldsymbol{S}_{j+1}}\right) \cdot (\Delta \boldsymbol{k}_{j+1} - \Delta \boldsymbol{k}_j)$$

- Case 1−2:

CASE	Enr.	CEr	H/U	K_{ben}	K_{cal}	ΔK	Δ(Δk)
(-)	(wt%)	(wt%)	(-)	(-)	(-)	(pcm)	(pcm)
1	5.4	0	277	0.9988	1.0015	270	-
2	5.4	0.3	277	0.9988	1.0021	330	**60**

Si	dk/k	dk	dσ/σ	dσ/σ
(-)	(-)	(pcm)	(-)	(%)
2.24E-02	6.01E-04	**60**	2.68E-02	**2.68**

$$\frac{\partial k}{k} = S_j \cdot \frac{\partial \sigma_i}{\sigma_i} \Longrightarrow \boxed{\frac{\partial \sigma_i}{\sigma_i} = \frac{\partial k/k}{S_j}}$$

- Case 3−2:

CASE	Enr.	CEr	H/U	K_{ben}	K_{cal}	ΔK	Δ(Δk)
(-)	(wt%)	(wt%)	(-)	(-)	(-)	(pcm)	(pcm)
3	5.4	0.3	91	0.9988	1.0007	190	-
2	5.4	0.3	277	0.9988	1.0021	330	**140**

Si	dk/k	dk	dσ/σ	dσ/σ
(-)	(-)	(pcm)	(-)	(%)
2.20E-02	1.36E-03	**137**	2.68E-02	**6.80**

$$Er_{unc} = \frac{60}{0.30} \approx \frac{170}{0.52} = 200 \div 260\ \frac{pcm}{wt\%}$$

- Case 4−5:

CASE	Enr.	CEr	H/U	K_{ben}	K_{cal}	ΔK	Δ(Δk)
(-)	(wt%)	(wt%)	(-)	(-)	(-)	(pcm)	(pcm)
4	9.6	0.6	48	0.9989	1.0020	310	
5	9.6	1.12	148	0.9989	1.0047	540	**230**

Si	dk/k	dk	dσ/σ	dσ/σ
(-)	(-)	(pcm)	(-)	(%)
2.25E-02	1.20E-03	**120**	2.68E-02	**2.84**

Note: The $\sigma_{Er^{167}}(n,\gamma)$ uncertainty appears to be major than the evaluated value reported in ENDF/B-VIII (**2.35%**).

IEU-COMP-THERM-013-001 (2011)

- The neutron radiography (NRAD) reactor is a 250 kW TRIGA Mark II tank-type research reactor located in the basement of the Hot Fuel Examination Facility (HFEF) at the Idaho National Laboratory (INL).
- It is primarily used for neutron radiography analysis of both irradiated and unirradiated fuels and materials.

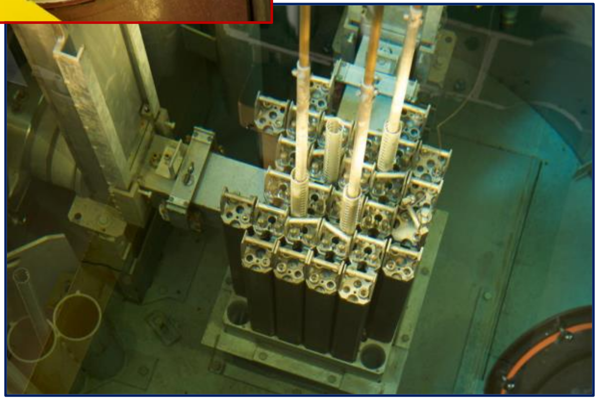


Table 1.2. Typical NRAD LEU (30/20) Fuel Design Parameters.(a)

Number of Fuel Elements	60
Fuel Type	UZrH-Er
Zirconium Rod Diameter	5.715 mm
Fuel Meat Outer Diameter	34.823 mm
Fuel Meat Length	381 mm
Clad Thickness	0.508 mm
Clad Material	304 SS
Total Uranium (wt.%)	30.0
Uranium Density (g/cm^3)	2.14
Weight of ^{235}U (g)	149.32
Weight of ^{238}U (g)	599.33
Uranium Enrichment (wt.%)	19.75
Total Fuel Weight (g)	2519
Erbium (wt.%)	0.90

- The TRIGA LEU (30/20) fuel is a mixture of U (30%wt, enr: 19.75 wt%), Er, and Zr hydride.

- The elements contain a uniform dispersion of 0.9 wt.% natural Er that is used as a burnable poison to offset initial reactivity of the fresh fuel and contribute to the prompt negative temperature coefficient.

IEU-COMP-THERM-013 (Benchmark cal.)

Table 4.1a. Comparison of Benchmark Eigenvalues (Case 1).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark k_{eff} ± σ	$\frac{C-E}{E}$ (%)
MCNP5	ENDF/B-VII.0	1.01412 ± 0.00007	1.0012 ± 0.0015	1.29
	JEFF-3.1	1.01174 ± 0.00007		1.05
	JENDL-3.3[(a)]	1.01094 ± 0.00007		0.97
	ENDF/B-VI.8[(b)]	1.00942 ± 0.00007		0.82
KENO-VI	ENDF/B-VII.0 (238-group)	1.01462 ± 0.00007		1.34
	ENDF/B-VII.0 (continuous energy)[(c)]	1.00945 ± 0.00008		0.82
SERPENT	ENDF/B-VII.0 (v. 1.1.17)	1.01402 ± 0.00008		1.28
	ENDF/B-VII.0 (v. 2.1.13)	1.01293 ± 0.00008		1.17

(a) S(α,β) data from the ENDF/B-VII.0 library were used with the JENDL-3.3 cross section data.
(b) ENDF/B-VII.0 cross section data for erbium isotopes were used.
(c) This value is calculated to be 1.01310 ± 0.00007 using updated thermal scattering data and treatments currently in the SCALE 6.2 software package (prerelease). Personal communication with B. J. Marshall at ORNL (June 17, 2013).

CASE	Enr.	Erbia	K_{ben}	Unc (1σ)	K_{cal}	Unc (1σ)	Δk_{best}
(-)	(wt%)	(wt%)	(-)	(-)	(-)	(-)	(pcm)
1	19.75	0.9	1.0012	0.0015	1.01412	0.00007	**1292**
2	19.75	0.9	1.0012	0.0015	1.01413	0.00007	**1289**

Table 4.1b. Comparison of Benchmark Eigenvalues (Case 2).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark k_{eff} ± σ	$\frac{C-E}{E}$ (%)
MCNP5	ENDF/B-VII.0	1.01413 ± 0.00007	1.0012 ± 0.0015	1.29
	JEFF-3.1	1.01181 ± 0.00007		1.06
	JENDL-3.3[(a)]	1.01116 ± 0.00007		0.99
	ENDF/B-VI.8[(b)]	1.00928 ± 0.00007		0.81
KENO-VI	ENDF/B-VII.0 (238-group)	1.01462 ± 0.00008		1.34
	ENDF/B-VII.0 (continuous energy)[(c)]	1.00937 ± 0.00008		0.82
SERPENT	ENDF/B-VII.0 (v. 1.1.17)	1.01409 ± 0.00008		1.29
	ENDF/B-VII.0 (v. 2.1.13)	1.01278 ± 0.00008		1.16

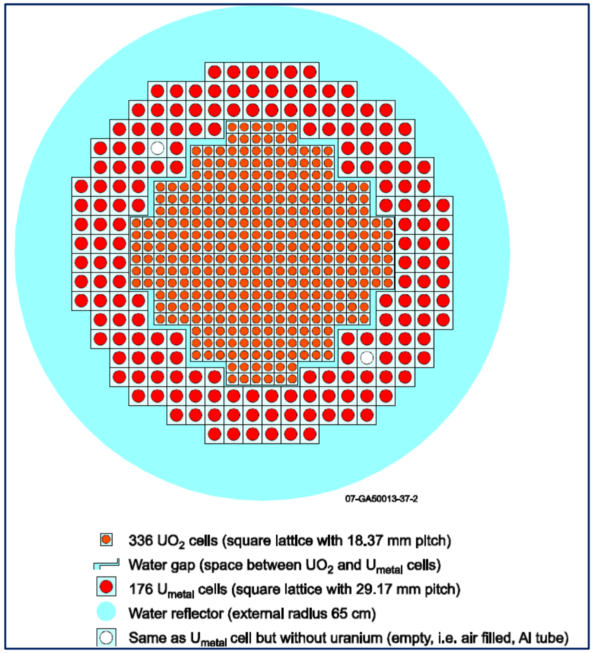
(a) S(α,β) data from the ENDF/B-VII.0 library were used with the JENDL-3.3 cross section data.
(b) ENDF/B-VII.0 cross section data for erbium isotopes were used.
(c) This value is calculated to be 1.01325 ± 0.00007 using updated thermal scattering data and

- The difference between calculated and experimental values (C – E) is not negligible (**~1300 pcm**);
- This difference is at least partly due to Erbia cross sections.

CROCUS-LWR-RESR-001 (2006)

- The CROCUS reactor, operated by the Swiss Federal Institute of Technology, is a simple two-zone uranium-fueled, H_2O-moderated critical research facility.
- The reactivity in the CROCUS reactor is controlled by the water level, which can be adjusted with an accuracy of ± 0.1 mm or ~ 0.4 pcm.

Parameter	Unit	UO_2	U_{metal}
Cladding thickness	mm	0.85±0.05	0.975±0.05
External cladding diameter	mm	12.60±0.1	19.3+0.1/-0.0
Fuel diameter	mm	10.520±0.017	17.00±0.02
^{235}U enrichment	wt.%	1.8060±0.0007	0.9470±0.0007
Square pitch	mm	18.370±0.002	29.170±0.002
Fuel density	g/cm^3	10.556±0.034 [a]	18.677±0.044 [a]



- Two absorber rods were used to perform kinetic measurements:
  1. Cylinder aluminum tube filled with water (~ 6770 ppm of Boron)
  2. Cylinder aluminium tube filled with pellet (ZrO_2 – Er_2O_3)

Parameter	Unit	Dimension
Outer diameter	mm	8.0+0.1/-0.0
Wall thickness	mm	1.00±0.05
Absorber B_{nat}: density	ppm in water at 20°C	6768±0.1%
Absorber Er: density	g/cm^3	4.594±1%
Absorber Er: pellet diameter	mm	5.89±0.2%

CROCUS-LWR-RESR-001 (benchmark cal.)

- With the absorber rod inserted, the reactor was made critical by adjusting the water level. Afterwards, the absorber rod was withdrawn, the water level being kept constant;

- Three different water level configurations and two supercritical configurations after withdrawing the absorber rods were measured.

Cross Sections used:

- ✓ HEXNOD: based mainly on ENDF/B
- ✓ MCU: based on ENDF/B-VI, JENDL-3.2 and BROND
- ✓ HELIOS: standard library in 45 energy groups
- ✓ BOXER: based on JEF-1 and BROND-2 for Er isotopes

Energy Groups used:

- ○ HEXNOD: 40 groups, condensed to 5 grps for 2D calc.
- ○ MCU: pointwise energy description
- ○ HELIOS: 45 groups, condensed to 12 groups
- ○ BOXER: based on 70 groups

Table 4.3. Calculated Reactivity ρ_{calc} [pcm] and Discrepancy of each Participant's Result against the Mean Value [pcm], and Uncertainty due to the Measured Inverse Period [pcm].

Results	Case 2 H_2	Case 3 H_3	Case 4 H_4	Case 5 Boron	Case 6 Erbium
Mean	88.4	109.6	130.5	83.8	169.6
HEXNOD	88.3 -0.1	109.3 -0.3	130.3 -0.2	--	--
MCU	88.4 +0.0	109.5 -0.1	130.6 +0.1	85.0 +1.2	179.5 +9.9
HELIOS	89.2 +0.8	110.9 +1.3	132.3 +1.8	81.3 -2.5	163.8 -5.8
BOXER	87.8 -0.6	108.6 -1.0	129.0 -1.5	85.1 +1.3	165.4 -4.2
$\Delta\rho_i(\omega)$	±0.40	±0.49	±0.58	±0.38	±0.76

- The point kinetics model was used to determine the reactivity through measure of the inverse period (ω) with the "*stable period method*" (T=1/ω).

$$\rho = \Lambda\omega + \sum_i \frac{\beta_i \omega}{\omega + \lambda_i}$$

- The largest discrepancy between calculated and mean values are in Case 6 (i.e., ~14 pcm) were erbium Xs may play a role as well as the resonance shielding calculations for Er isotopes **[10]**.

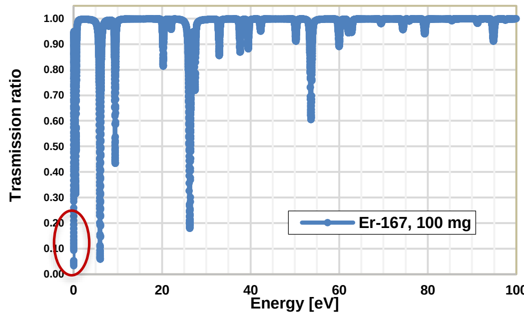
Evaluation of the mass sample

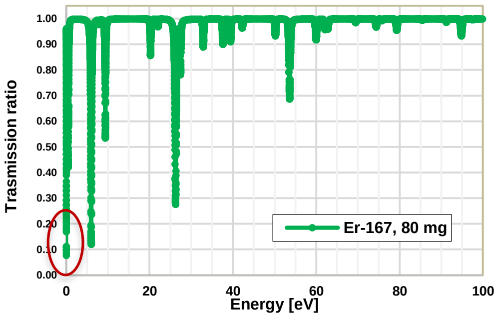
- A preliminary evaluation of the Er-167 and Er-nat mass to have to use in the sample (metal disc with a radius of 1 cm) for the Xs measurements was performed on the basis of different TR.

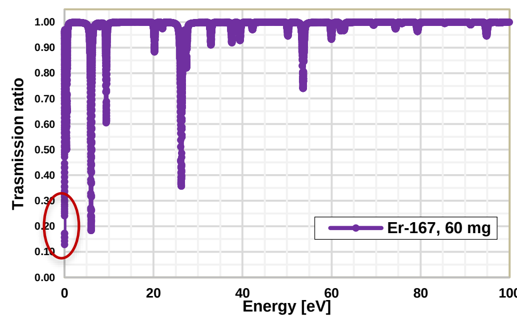
Areal density calculation				
Isotope	Atomic Weight	mass	mass	ρa
(-)	(g/mol)	(mg)	(atom)	(atom/barn)
Er-167	167	**100**	3.61E+20	1.15E-04
		75	2.71E+20	8.61E-05
		60	2.17E+20	6.89E-05
		50	1.80E+20	5.74E-05

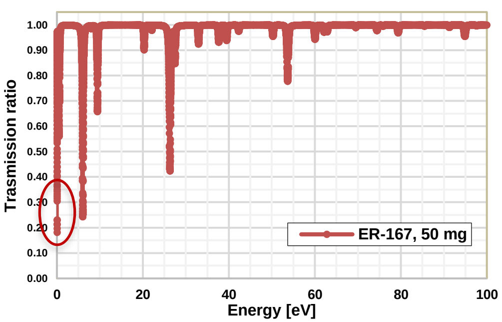
	Mass (mg)			
Er-167	**100**	**75**	**60**	**50**
Er-nat	**440**	**330**	**260**	**220**

$$\rho_{Er} = 9.2\ g/cm^3$$







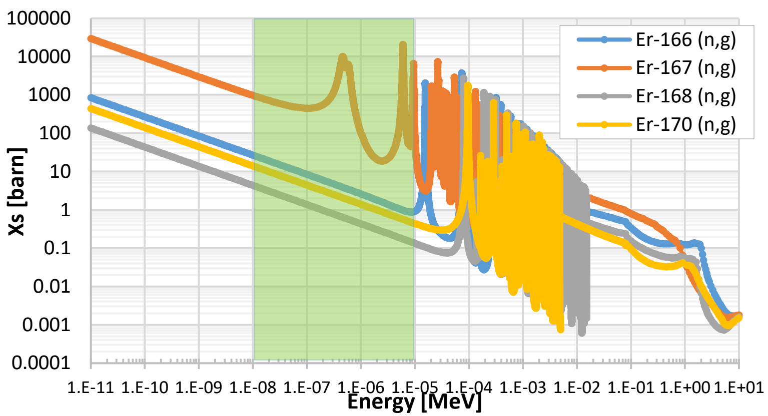


To avoid background interference, the trasmission ratio (TR) have to be greater than 0.15 − 0.20.

$$TR \geq 0.15 \div 0.20 \implies m_{Er-167} \leq 50\ mg;\ \ m_{Er-nat} \leq 220\ mg$$

Updates 1: Isotopes cost

- **Isotopes cost**: U.S. National Isotope Development Center (NIDC), responded to a quote request **[1]**:
- **Er-167:** 50 mg, 449 $ (~ 376 €), but a minimum quantity of 100 mg would be cleared for shipping (to verify).
- **Packaging fee**: 2,415 $ (~ 2023 €).
- **Er-nat:** 200 mg, 65 $ (~ 54 €), 100 mg is the minimum quantity that it would probably be shipped (to verify). **[2]**
- **Comment:** Due to the isotopes Xs(n,g) ratio, a measurement of Er-nat sample would be enough to evaluate Er-167 (n,g) in the thermal range.



National Isotope Development Center
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6158

Isotope Quotation

Quotation	3006713
Date	01/11/2021
Quotation Period	01/11/2021 to 02/15/2021
Terms of Payment	Advance Payment Request
Terms of Delivery	FCA DOE Facility

Customer Reference: NIDC_Order 12574

Quotation For: 999000

ENEA
ANTONIO GUGLIELMELLI
VIA MARTIRI DI MONTE SOLE N° 4
40129 BOLOGNA BO
ITALY

Refer Questions To:

Betty Lane
Phone: 865-574-7415
Email: lanebs@ornl.gov

SALE IS SUBJECT TO DOE APPROVAL

Item	Description	Quantity	Price per Unit (USD)		Value
0010	ER-166 Erbium 166 Chemical Form: Erbium oxide Assay: 96.3100% Batch: 173392	1,000.000 MG	3.42	1 MG	3,420.00
0011	ZZ-S11 EM Isotope Conversion Services Conversion of oxide to metal	1.000 LOT	5,130.00	1 LOT	5,130.00
0020	ER-167 Erbium 167 Chemical Form: Erbium metal solid Assay: 91.5200% Batch: 173441	100.000 MG	8.98	1 MG	898.00
0030	ER-168 Erbium 168 Chemical Form: Erbium metal solid Assay: 95.4800% Batch: 173545	100.000 MG	4.37	1 MG	437.00
0040	ER-170 Erbium 170 Chemical Form: Erbium metal solid Assay: 96.9300% Batch: 173641	1,000.000 MG	12.00	1 MG	12,000.00
0050	ZZ-S01 EM Stable Isotope Packaging Fee	1.000 LOT	2,415.00	1 LOT	2,415.00

[1] In date 16/11/2020 a request was sent by e-mail, on 11/01/2021 NIDC replied by e-mail.

[2] Erbium cost available on-line from: https://www.chemicool.com/elements/erbium.html

Updates 2: GELINA feedback

- The GELINA scientific senior group (Carlos Paraela, Peter Schillebeeckx, Stefan Kopeky) have positively evaluated this proposal;
- Further investigations have been requested on:
  1. The research activities status of "*erbia burnable absorber*";
  2. The "*in-core use*" of erbium, particularly in the EU countries.
- Based on the ICSBEP analysis, it was also suggested to submit a request at OECD-NEA databank to put Er(n,g) in High Priority Request List (HPRL);
- The HPRL request has already been prepared and will be submitted in the next weeks.
- A scientific article on "*Scientific motivation for a new erbium isotopes capture cross section measurement*" is in progress and will be finalized in the next months.

SG-C Working document 24/06/2021 11:59:00

HPRL Request Form

Information below can be entered using the online form on the HPRL webpage:
http://www.oecd-nea.org/dbdata/hprl/requestform.html

Detailed explanations on all fields and on the submission procedure are available online:
http://www.oecd-nea.org/dbdata/hprl/guidelines.html

If there is any problem with the online procedure, please complete the information below, add references if necessary, and send this to emmeric.dupont@cea.fr.

Requester *(Each request should be "owned" by a single individual)*

Dr. Antonio Guglielmelli, Ph.D.
e-mail: antonio.guglielmelli@enea.it
Organization: Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)
Country: Italy

Target Z, A
Target Z: 68-Er
Target A: 166, 167, 168, 170

Reaction/Process *(Physical reaction process, e.g., fission, scattering, etc.)*
(n,g)

Quantity *(Quantity of the reaction process that is of concern to the requester, e.g., cross section, resonance parameter, spectrum, average multiplicity, etc.)*
SIG (cross section), SIG-RP (Resonance parameters)

Incident energy range *(Energy range of the incident particle in the laboratory)*
0.01 – 100 eV

Secondary energy/angle *(If differential or double-differential data are requested, then the energy and angular ranges for the emitted particle need to be specified)*
...

Covariance information: Yes/No *(If there is no request for covariance information, then it will be assumed that knowledge of the standard deviations alone is adequate)*
Yes

Thank you for attention!

Antonio Guglielmelli
antonio.guglielmelli@enea.it