MODELOWANIE ZATRUĆ W BLOKU BERYLOWYM

BERYLLIUM POISONING MODEL DEVELOPMENT AND EXPERIMENTAL VALIDATION IN RESEARCH REACTORS WITH EXPLOITATION IN MARIA AND JULES-HOROVITZ REACTORS

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Praca wykonana w ramach projektu BENICE

Presentation overview

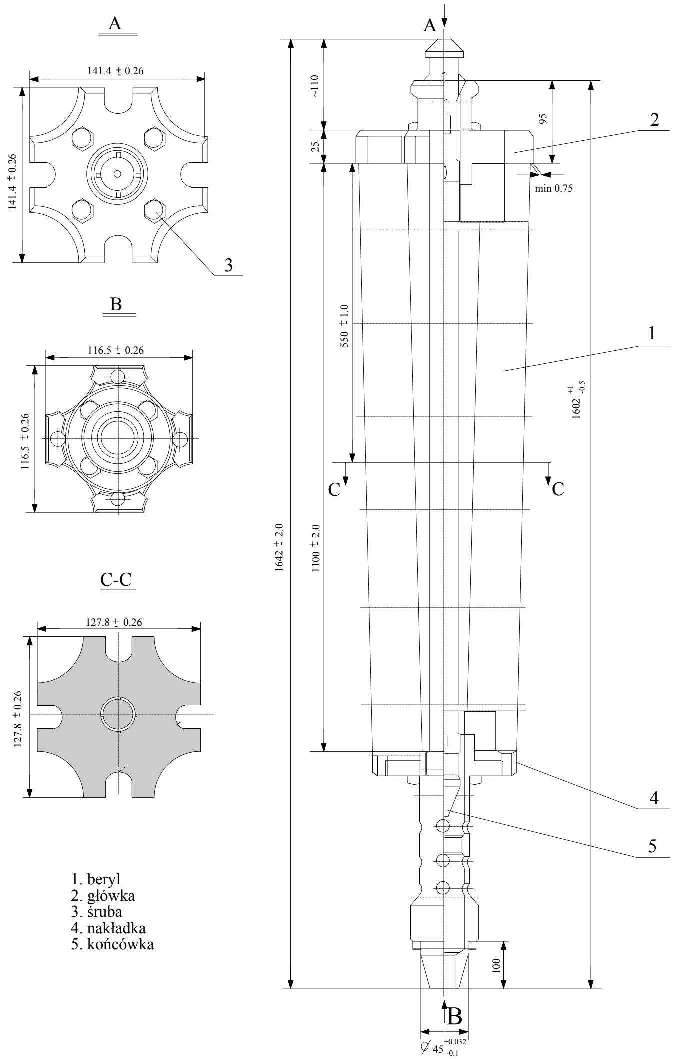
- Theoretical background
- Codes and methods
- Results
- Summary
- What’s next?

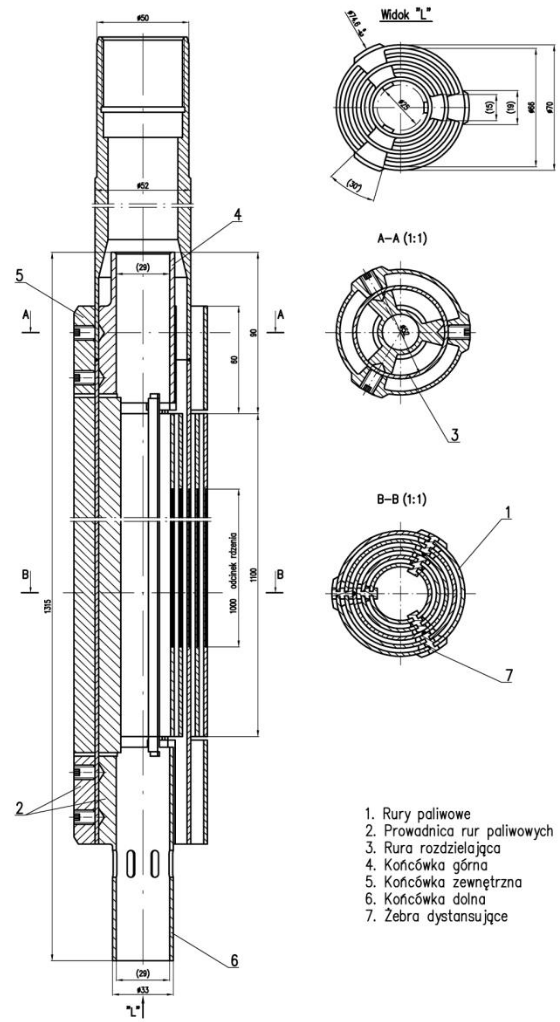
Some theory…

MARIA :

- pool type reactor
- power of 20-30 MWth
- moderated with water and beryllium
- $3 \cdot 10^{14}\ n/cm^2 \cdot s$
- fuel: CERCA LEU, 19.75% enriched

Fuel and beryllium





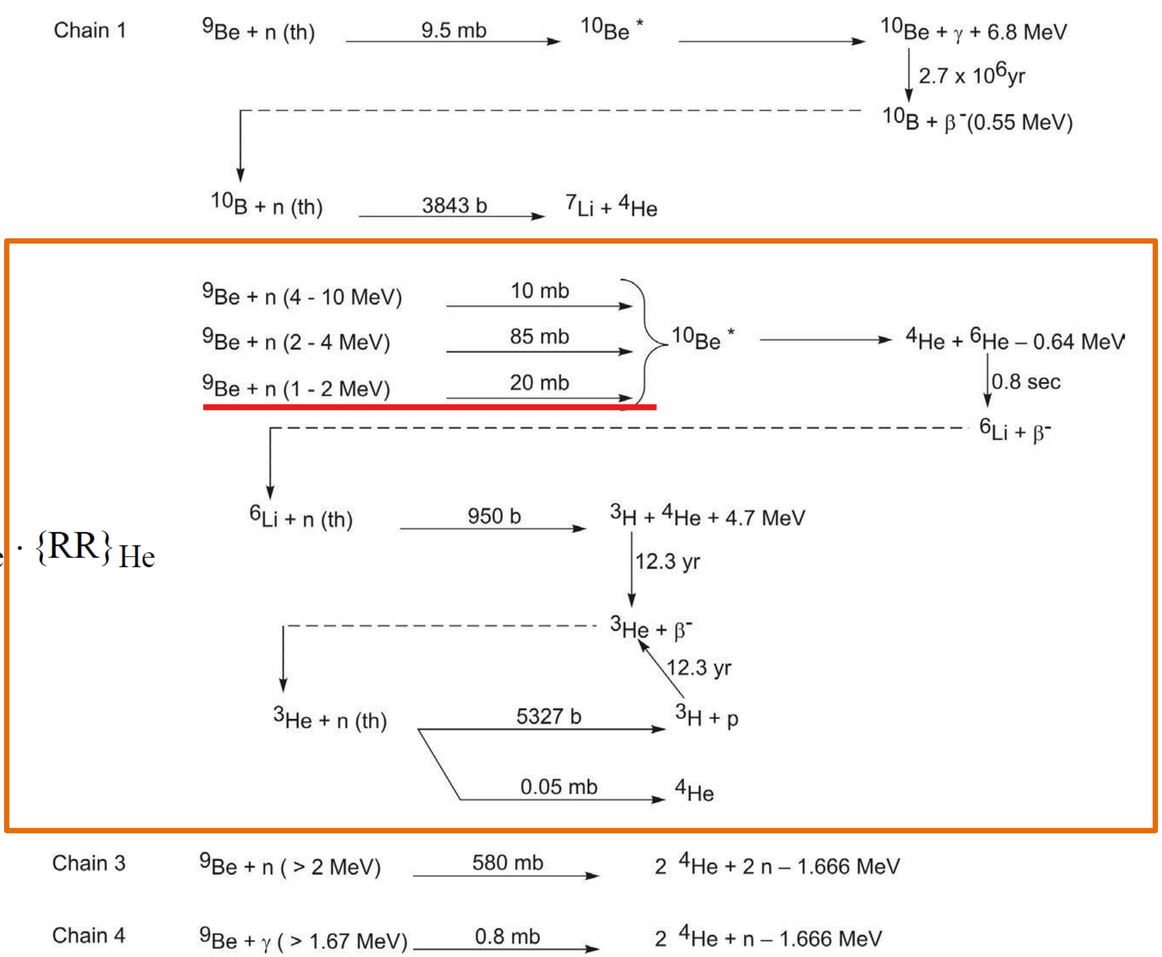
Poisoning

$$\frac{dN_{Be}}{dt} = -N_{Be} \cdot \{RR\}_{Be}$$

$$\frac{dN_L}{dt} = N_{Be} \cdot \{RR\}_{Be} - N_L \cdot \{RR\}_L$$

$$\frac{dN_T}{dt} = N_L \cdot \{RR\}_L - \lambda_T \cdot N_T + N_{He} \cdot \{RR\}_{He}$$

$$\frac{dN_{He}}{dt} = \lambda_T \cdot N_T - N_{He} \cdot \{RR\}_{He}$$



Codes and methods

TRANSPORT CODE

- APOLLO2 (CEA France) :
  - CP method; CEA2005 libraries v10.4; XMASS 172 group structure and Pij solver.
  - MOC method; SHEM 281-group energy mesh

MONTE CARLO

- TRIPOLI4 (CEA France)
- SERPENT 2.1.23 (VVT Finland)
- MCNP (LANL USA)

Codes and methods

APOLLO2

- Collision Probability Method and Method of Characteristics
- 172 and 281 energy group library
- self-shelding calculations
- various energy cutting (69 groups and no cutting)
- beryllium depletion in calculations
- steady state calculation
- burnup calculations
- two types of calculation cell considered

Codes and methods

SERPENT

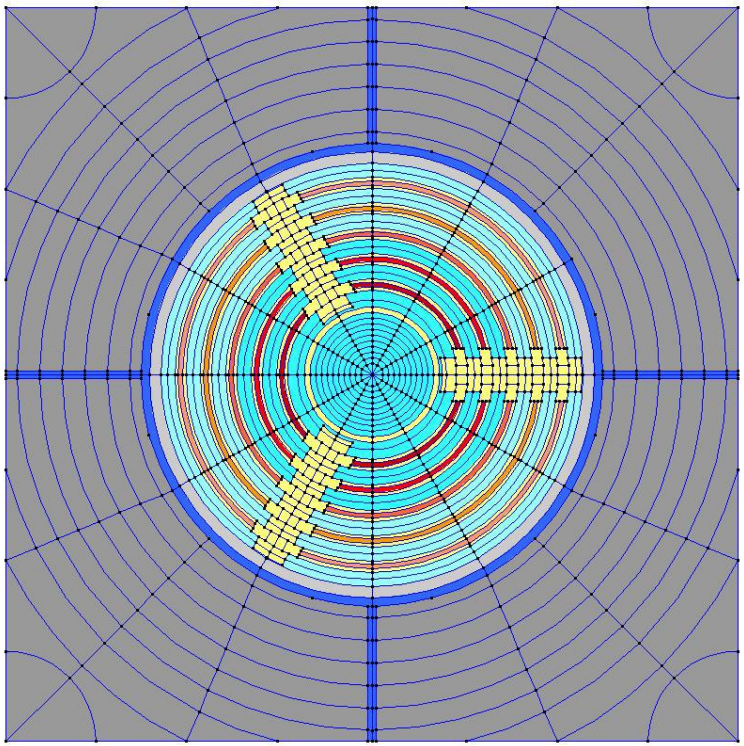
- cold operating conditions
- burnup with 3 schemes
- cumulative burnup steps, outage calculated at the end
- cumulative burnup steps, outage calculated after each cycle
- time steps, outage calculated after each cycle

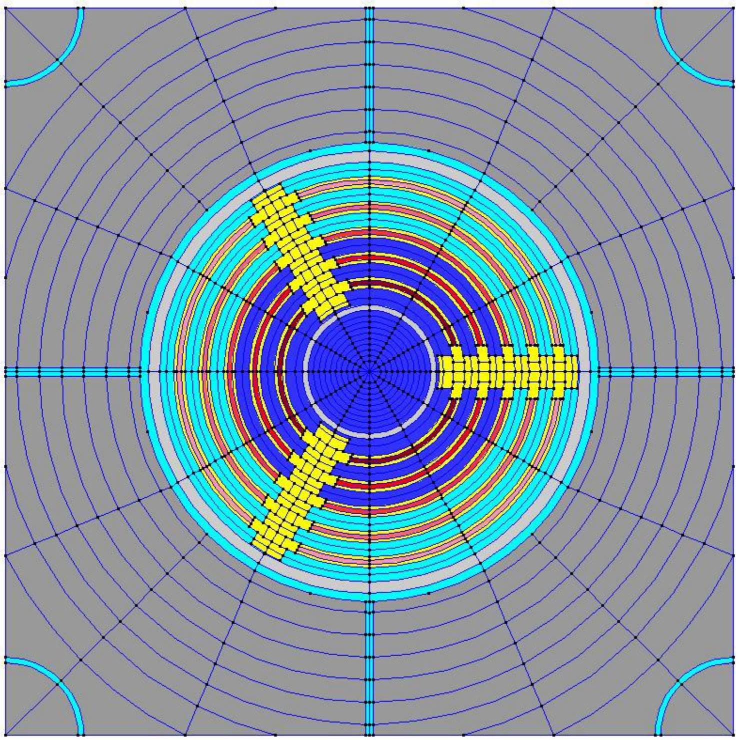
TRIPOLI4

- cold opetating conditions

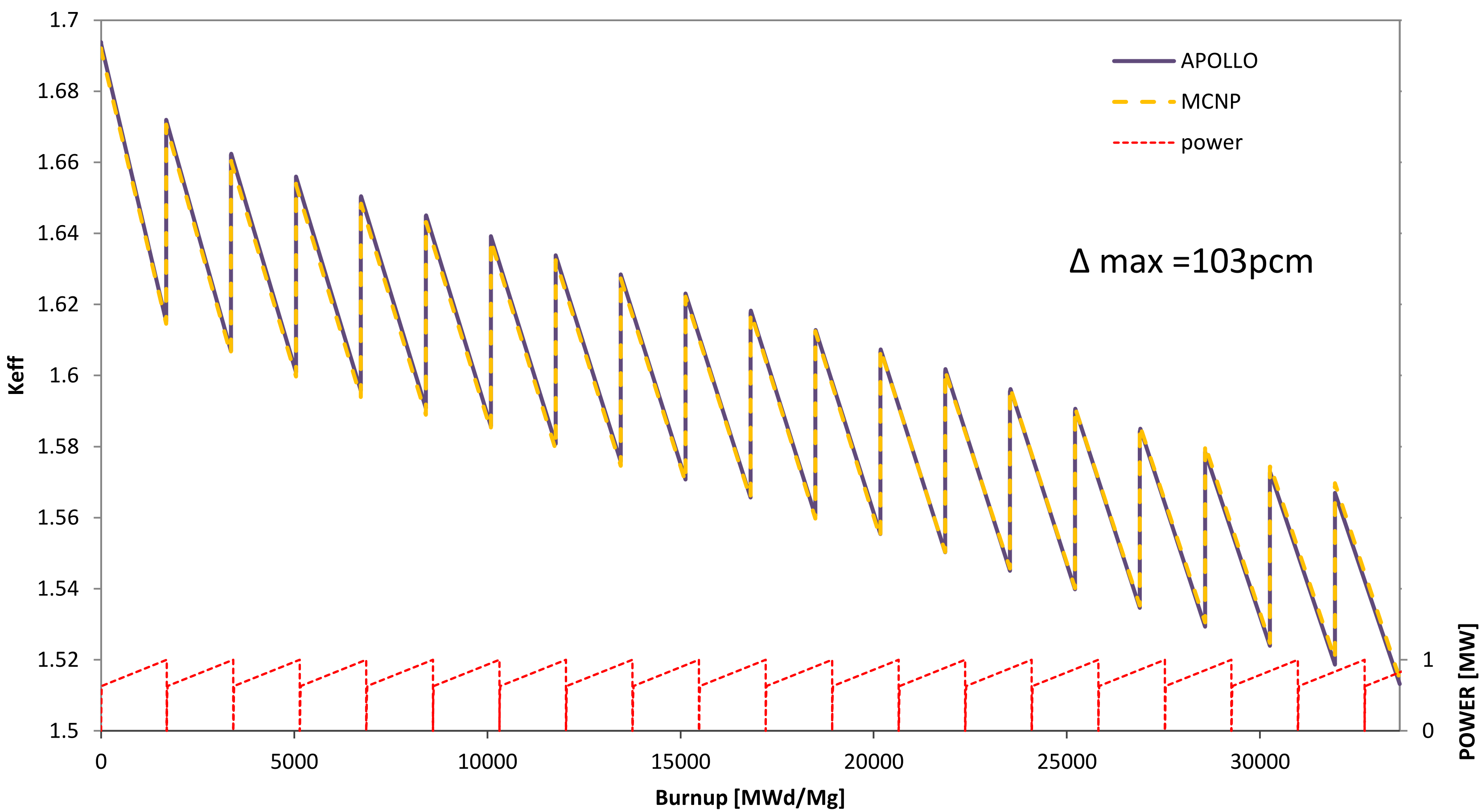
Codes and methods

GEOMETY



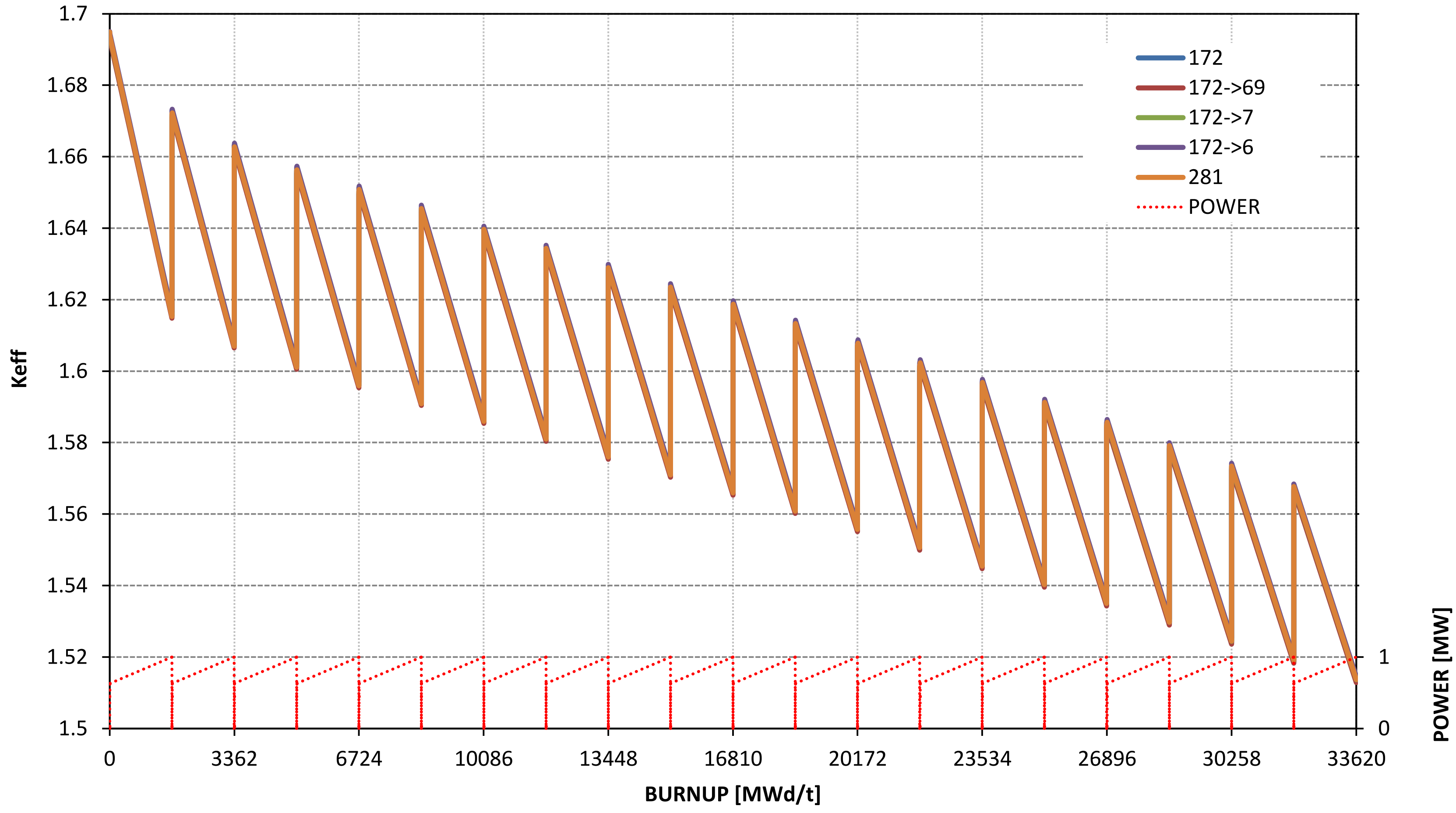


RESULTS



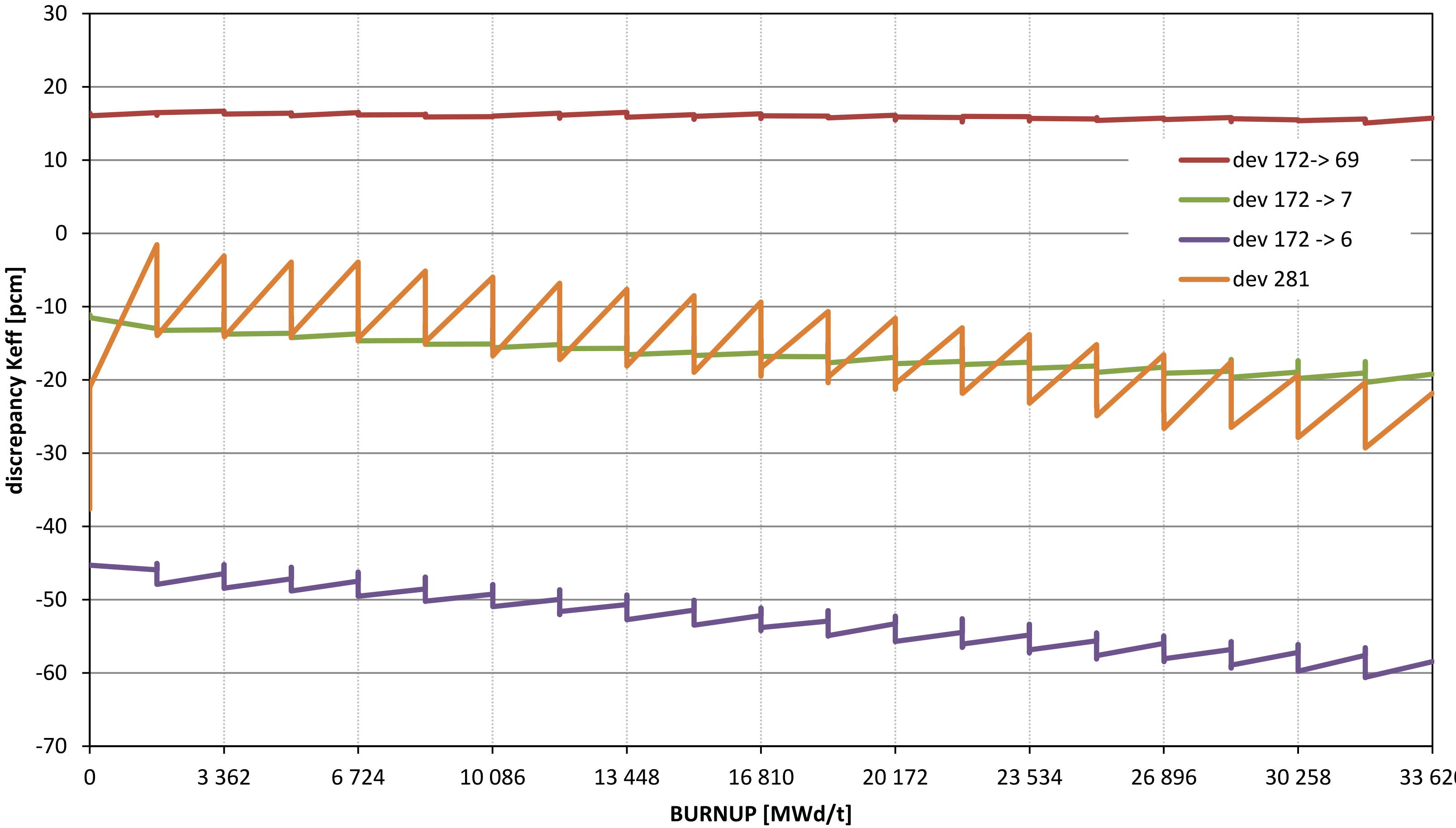
APOLLO
MCNP
power
Δ max =103pcm
Keff
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
0
5000
10000
15000
20000
25000
30000
Burnup [MWd/Mg]
POWER [MW]
1
0

RESULTS



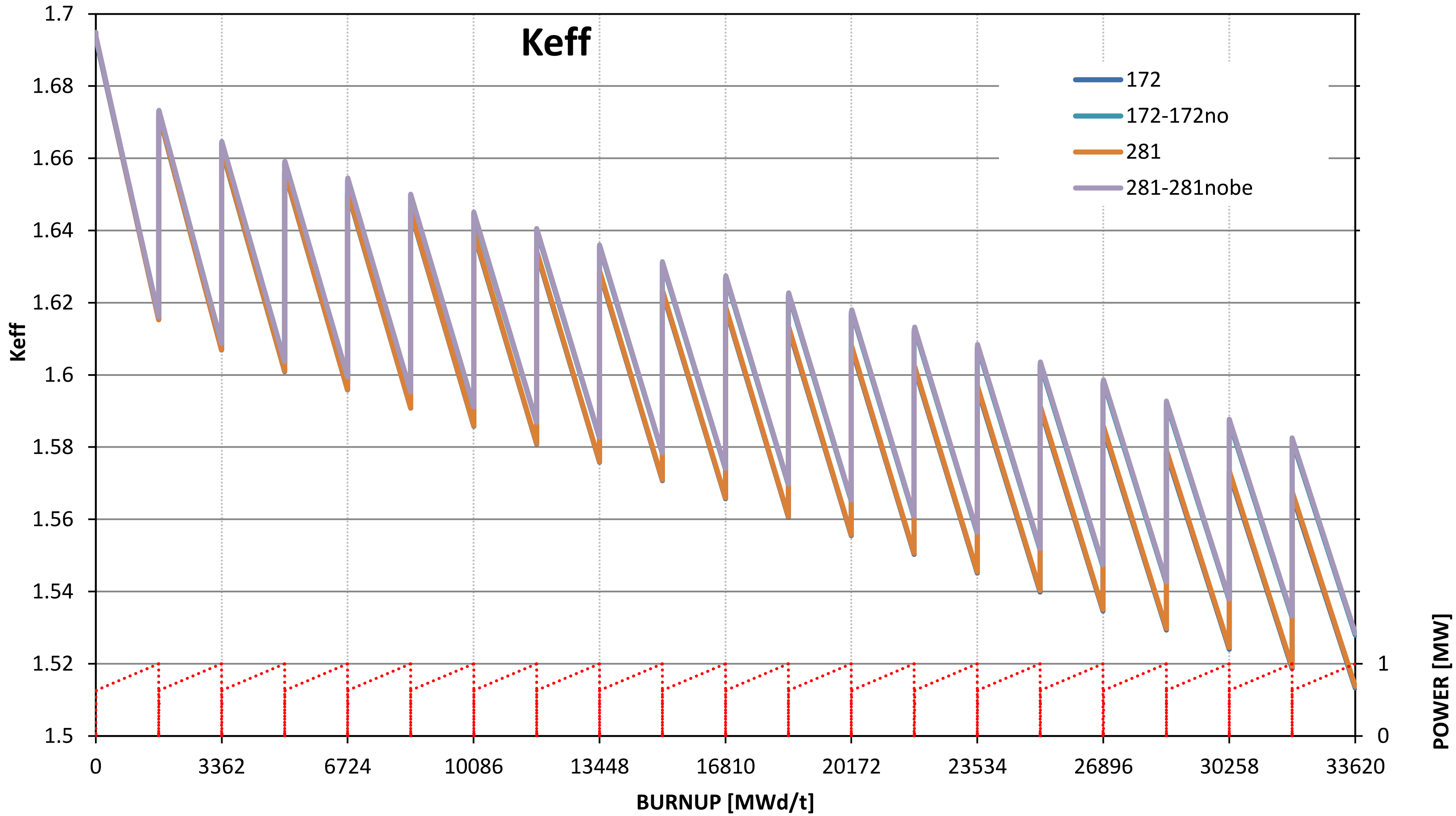
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
Keff
0
3362
6724
10086
13448
16810
20172
23534
26896
30258
33620
BURNUP [MWd/t]
1
0
POWER [MW]
172
172->69
172->7
172->6
281
POWER

RESULTS



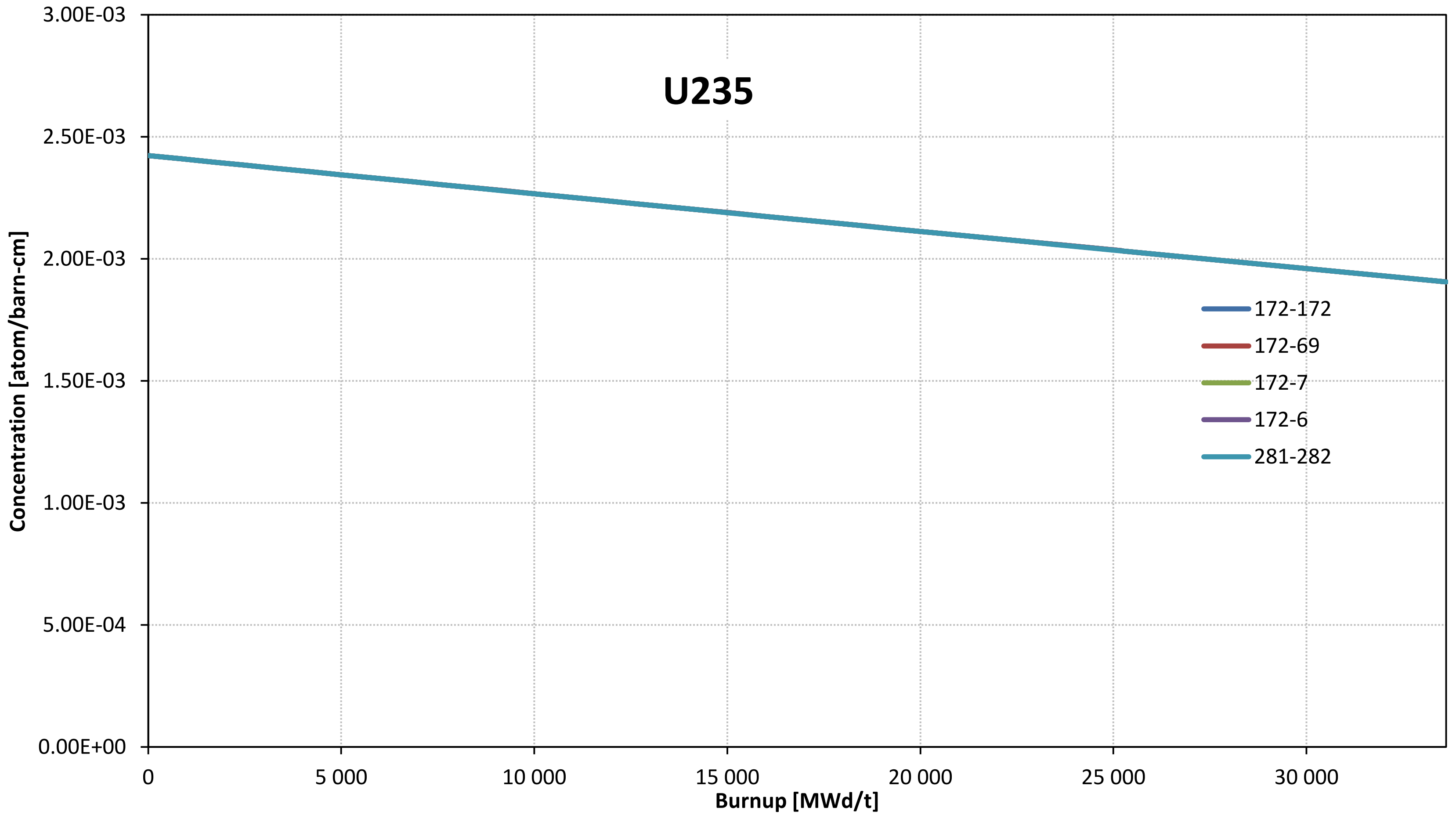
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
discrepancy Keff [pcm]
0
3 362
6 724
10 086
13 448
16 810
20 172
23 534
26 896
30 258
33 620
BURNUP [MWd/t]
dev 172-> 69
dev 172 -> 7
dev 172 -> 6
dev 281

RESULTS



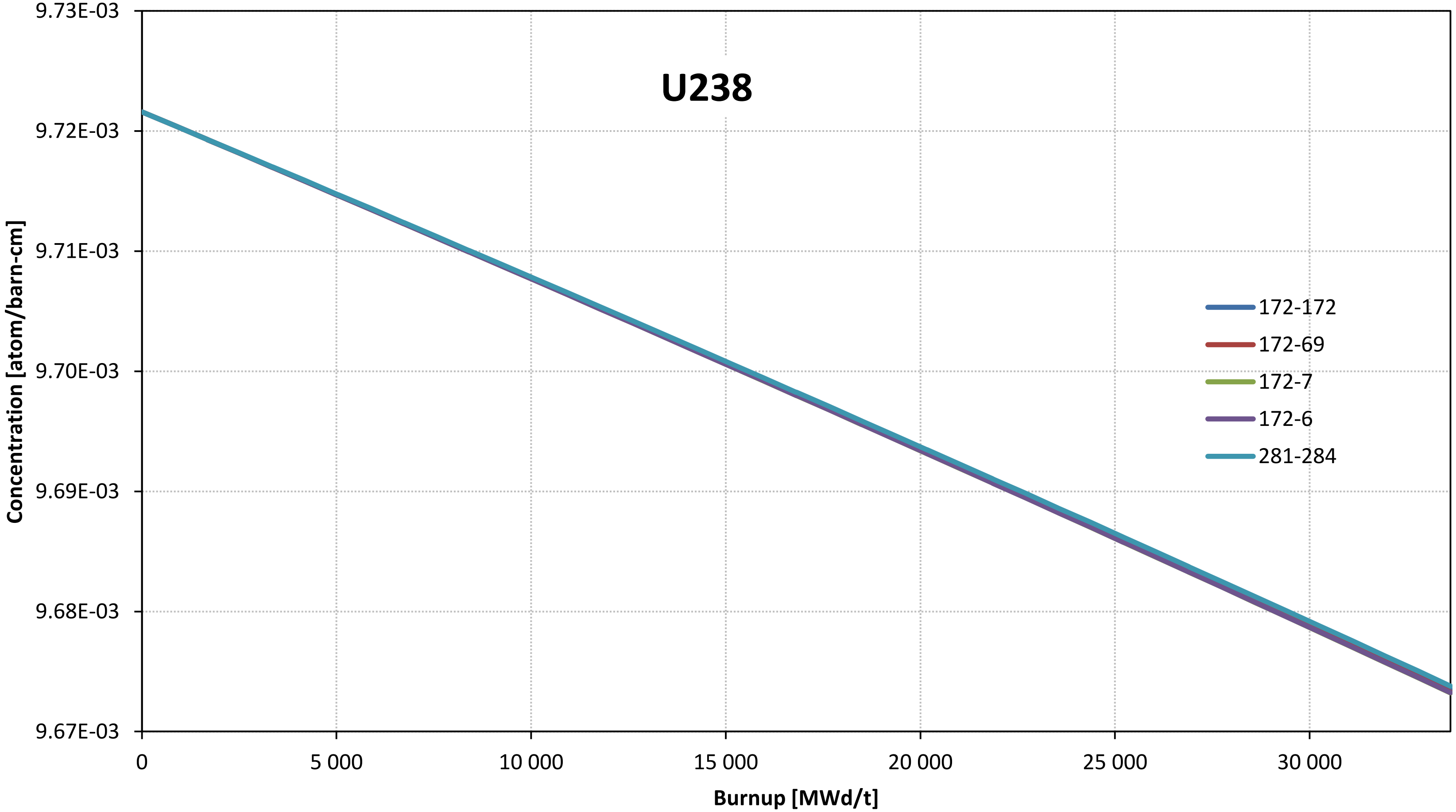
Keff
172
172-172no
281
281-281nobe
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
Keff
0
3362
6724
10086
13448
16810
20172
23534
26896
30258
33620
BURNUP [MWd/t]
1
0
POWER [MW]

RESULTS



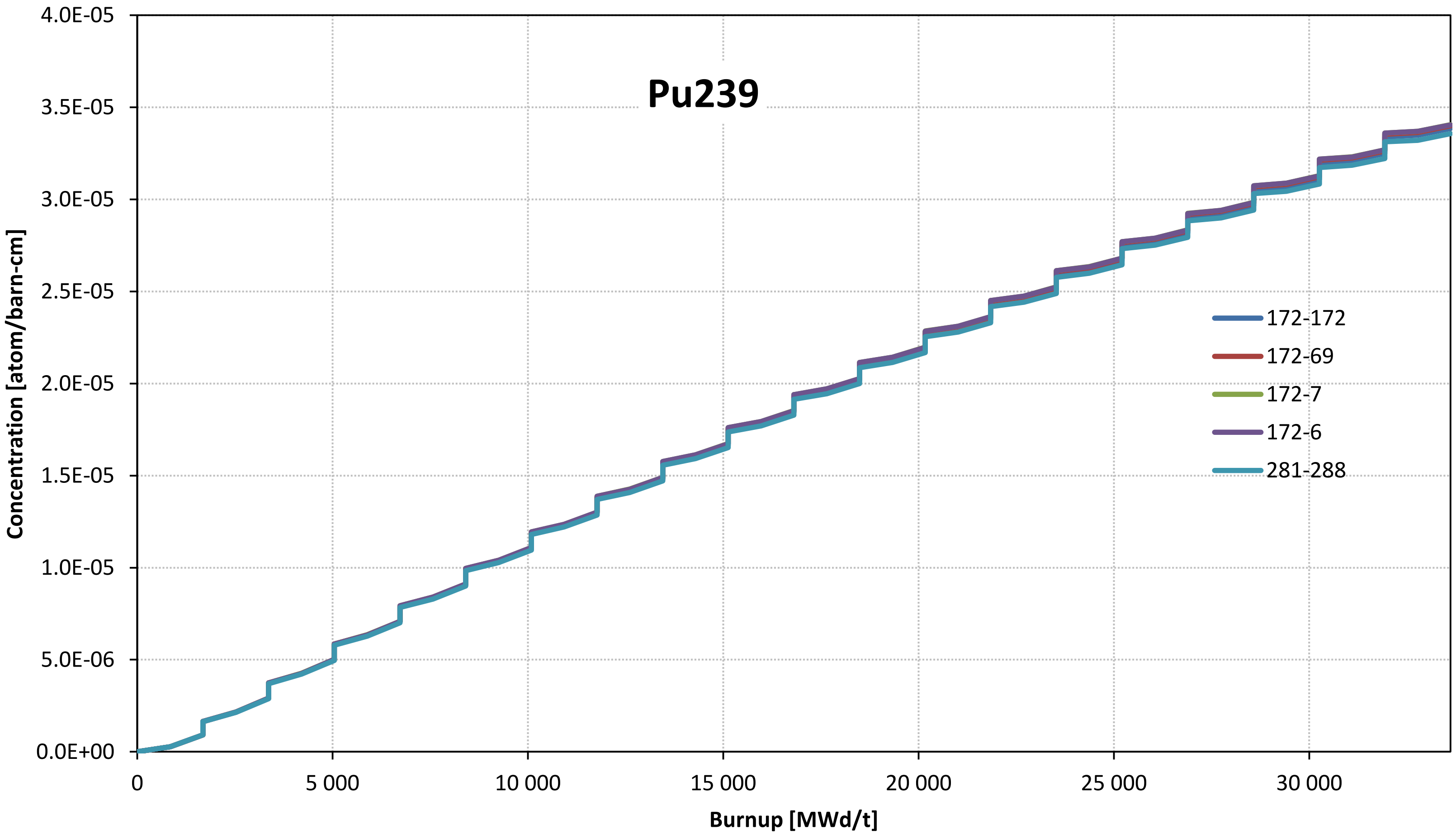
U235
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
Concentration [atom/barn-cm]
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]
172-172
172-69
172-7
172-6
281-282

RESULTS



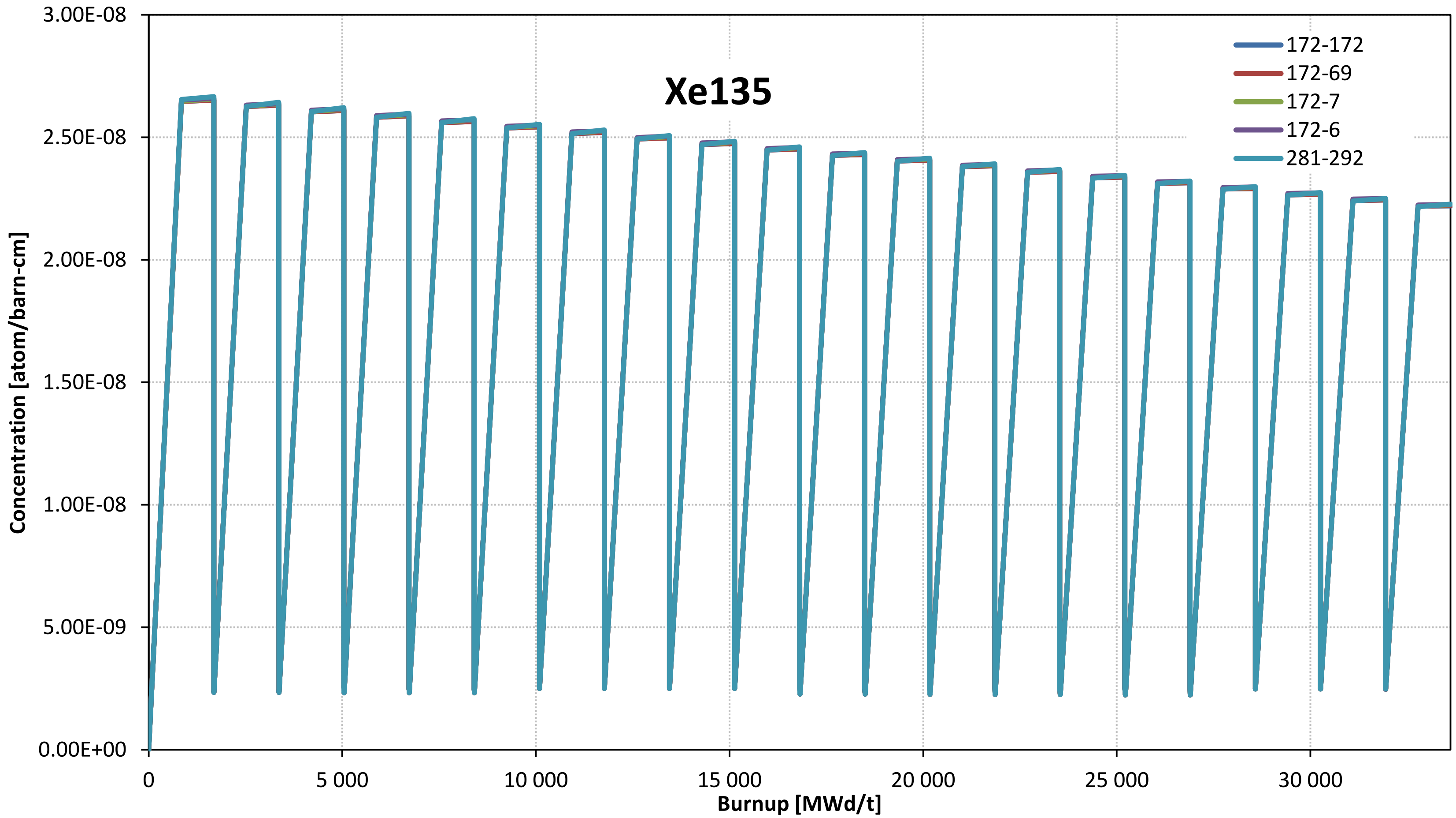
U238
9.73E-03
9.72E-03
9.71E-03
9.70E-03
9.69E-03
9.68E-03
9.67E-03
Concentration [atom/barn-cm]
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]
172-172
172-69
172-7
172-6
281-284

RESULTS



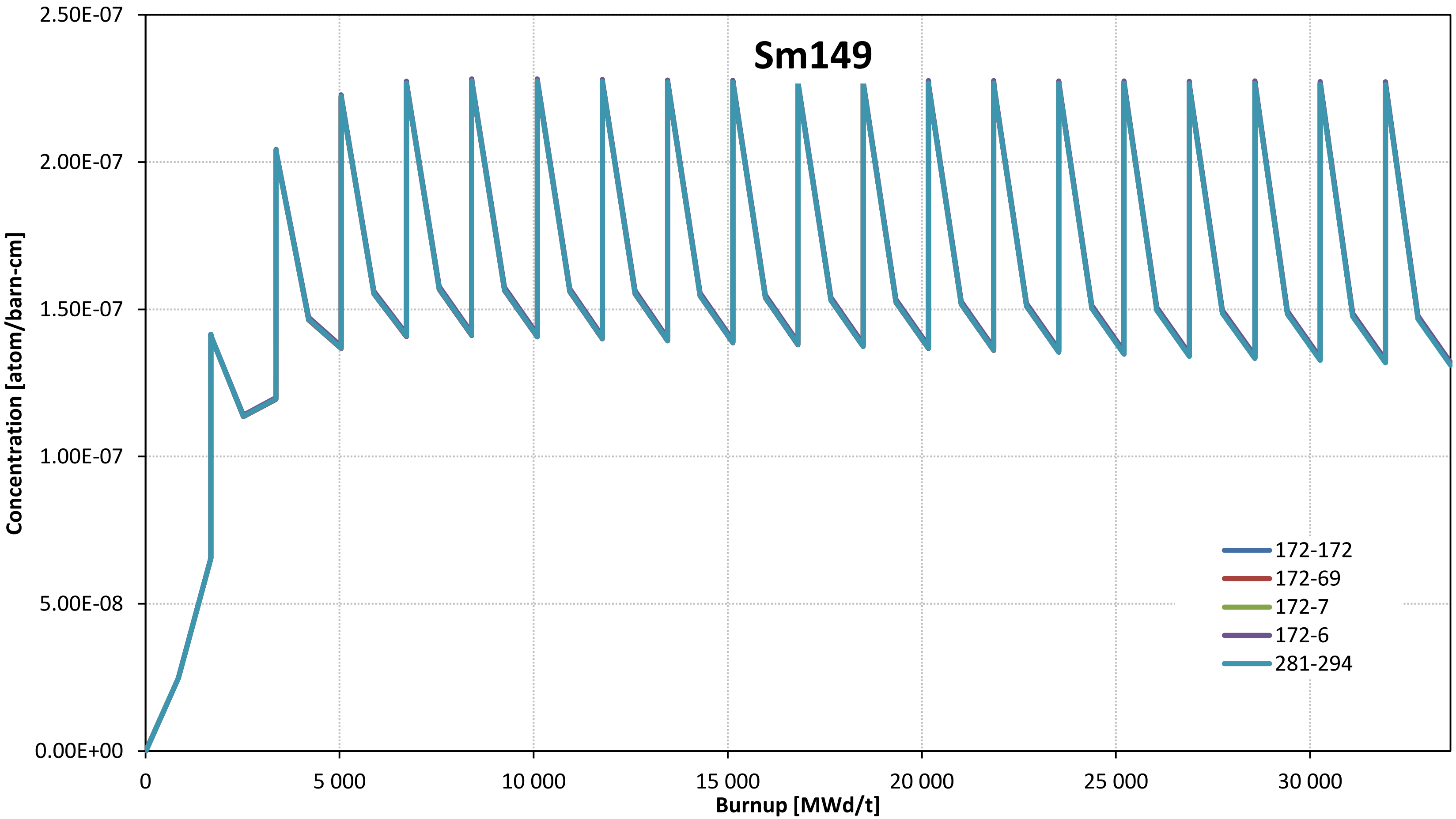
Pu239
Concentration [atom/barn-cm]
4.0E-05
3.5E-05
3.0E-05
2.5E-05
2.0E-05
1.5E-05
1.0E-05
5.0E-06
0.0E+00
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]
172-172
172-69
172-7
172-6
281-288

RESULTS



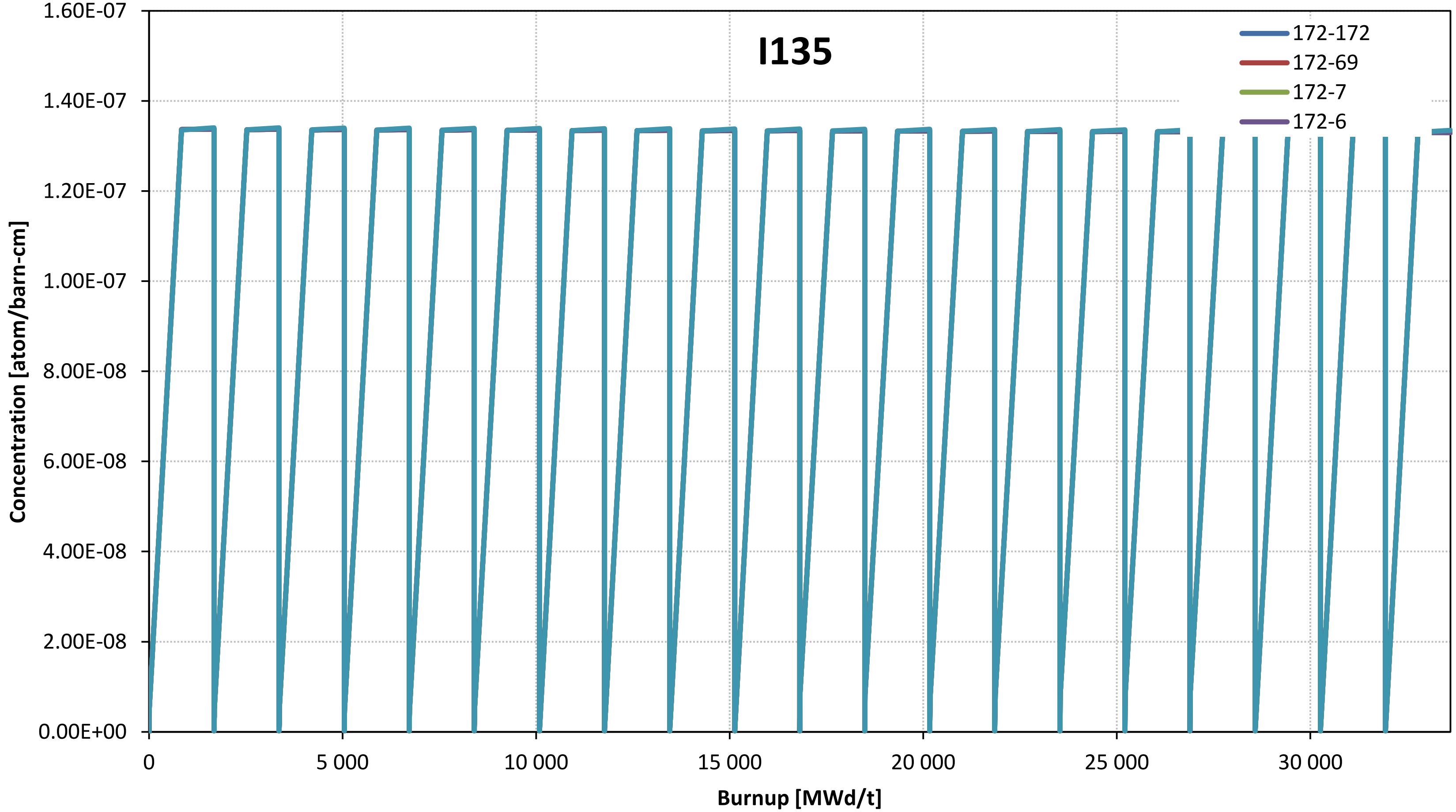
Xe135
172-172
172-69
172-7
172-6
281-292
Concentration [atom/barn-cm]
3.00E-08
2.50E-08
2.00E-08
1.50E-08
1.00E-08
5.00E-09
0.00E+00
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]

RESULTS

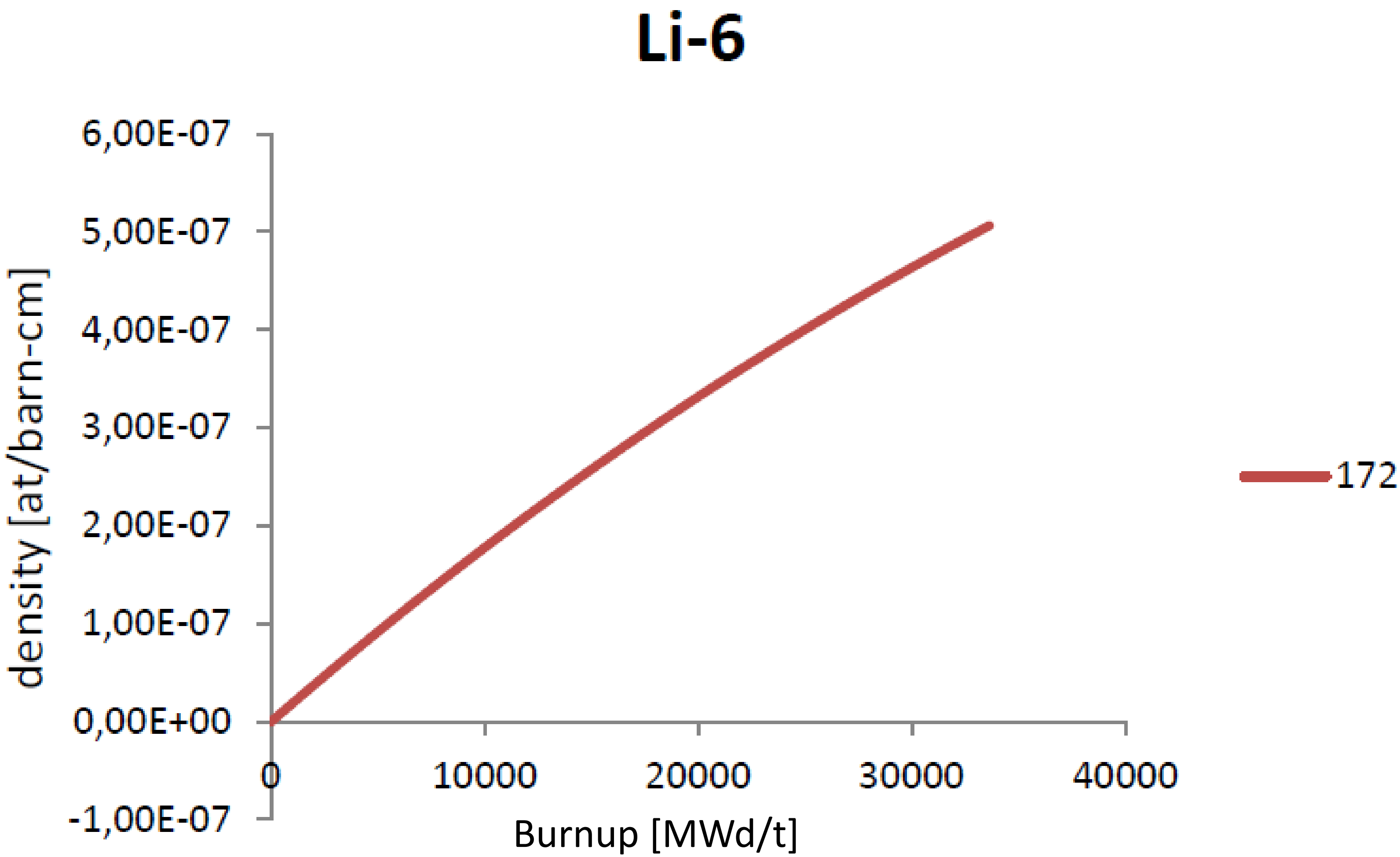


Sm149
2.50E-07
2.00E-07
1.50E-07
1.00E-07
5.00E-08
0.00E+00
Concentration [atom/barn-cm]
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]
172-172
172-69
172-7
172-6
281-294

RESULTS

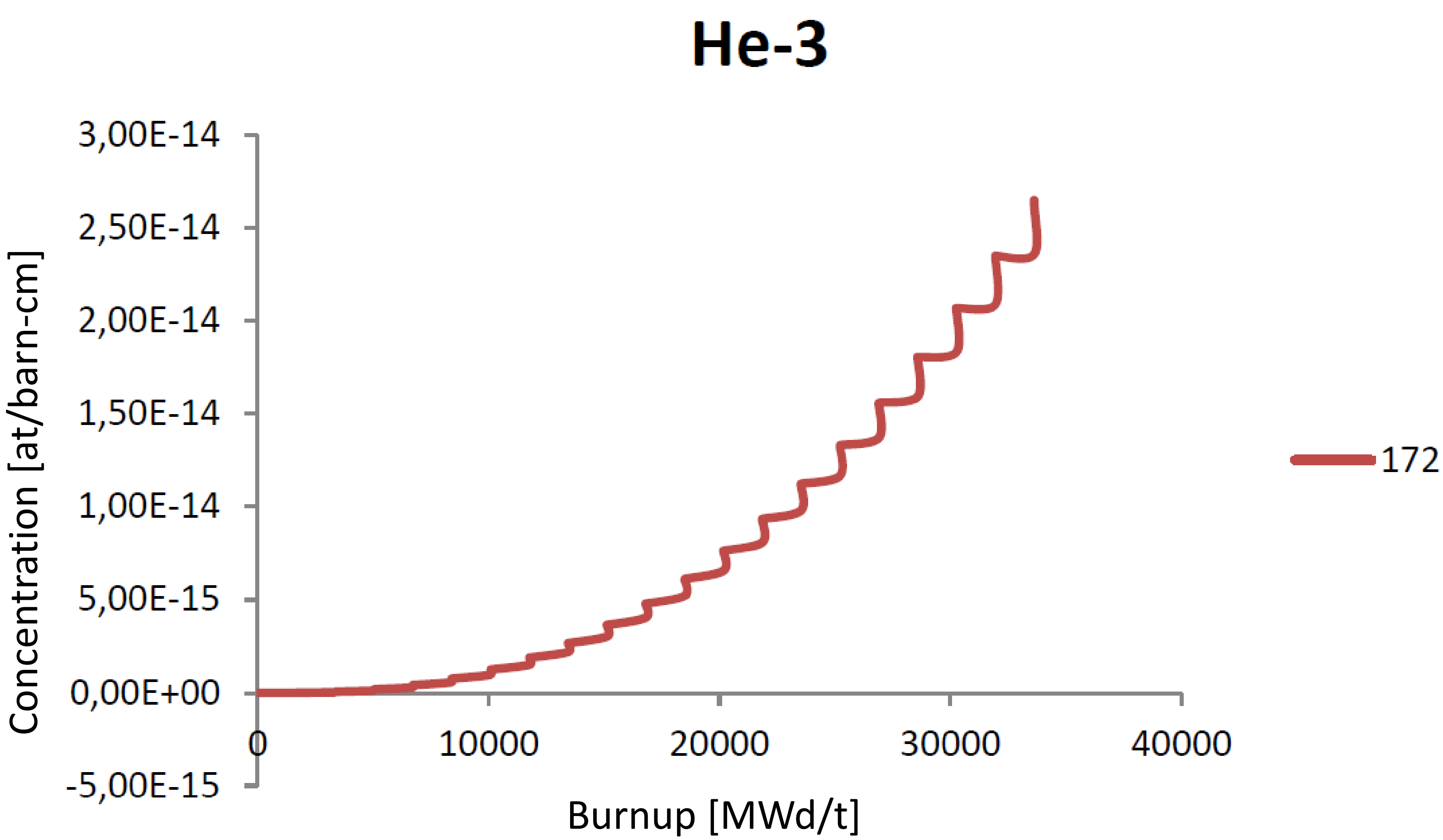

I135
172-172
172-69
172-7
172-6
1.60E-07
1.40E-07
1.20E-07
1.00E-07
8.00E-08
6.00E-08
4.00E-08
2.00E-08
0.00E+00
Concentration [atom/barn-cm]
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]

RESULTS



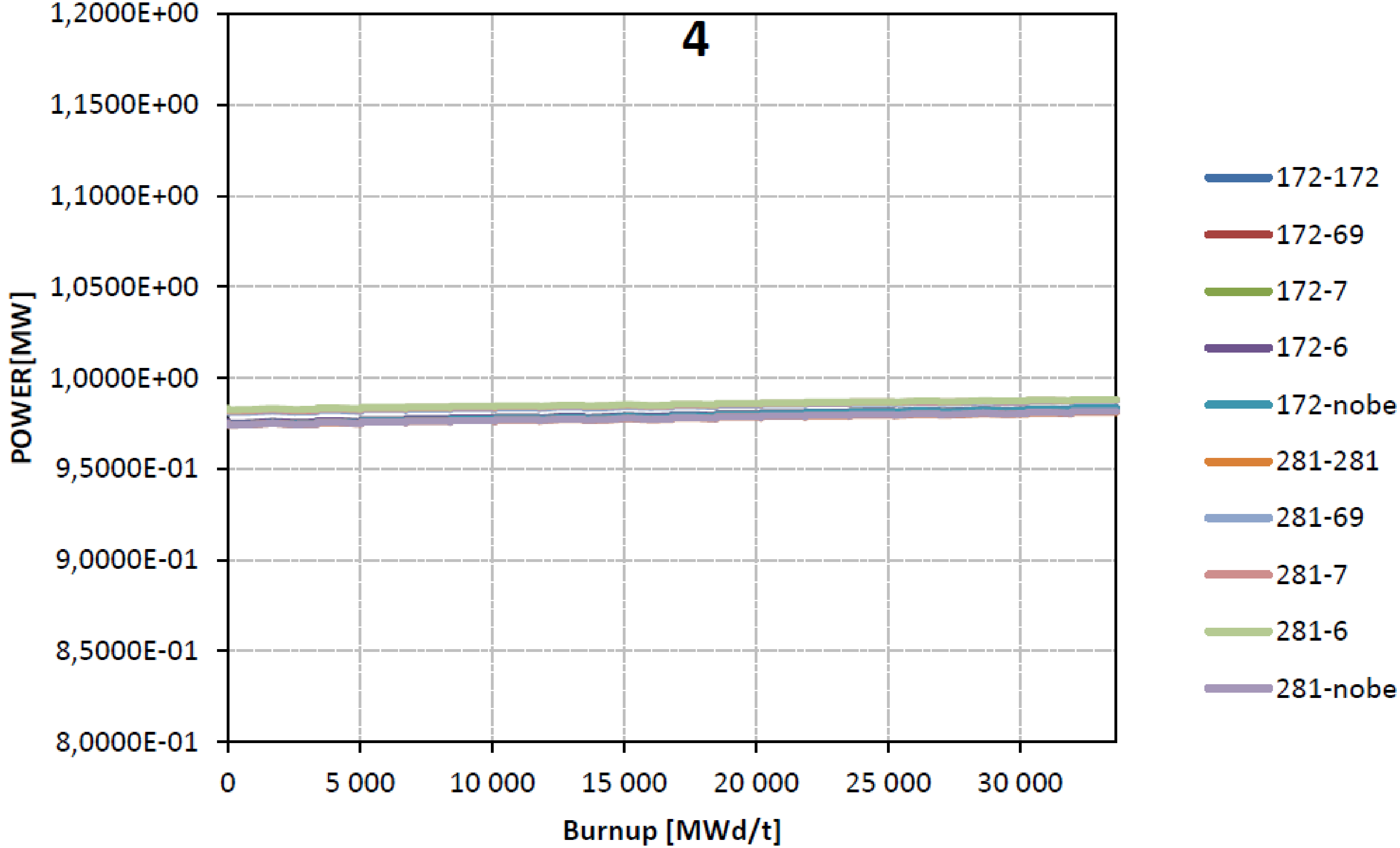
Li-6
6,00E-07
5,00E-07
4,00E-07
3,00E-07
2,00E-07
1,00E-07
0,00E+00
-1,00E-07
density [at/barn-cm]
0
10000
20000
30000
40000
Burnup [MWd/t]
172

RESULTS



He-3
3,00E-14
2,50E-14
2,00E-14
1,50E-14
1,00E-14
5,00E-15
0,00E+00
-5,00E-15
0
10000
20000
30000
40000
Concentration [at/barn-cm]
Burnup [MWd/t]
172

RESULTS

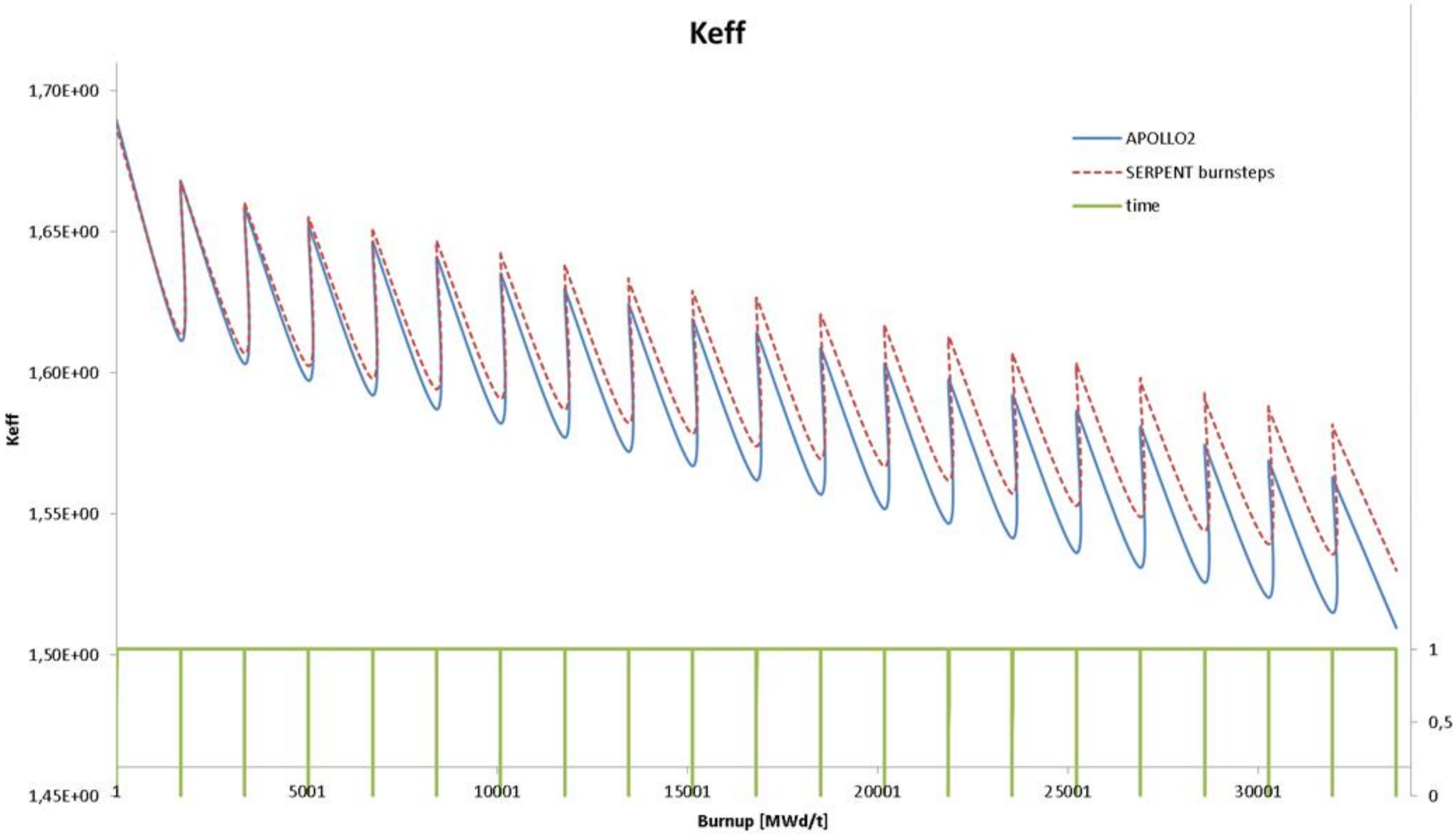

4
1,2000E+00
1,1500E+00
1,1000E+00
1,0500E+00
1,0000E+00
9,5000E-01
9,0000E-01
8,5000E-01
8,0000E-01
POWER[MW]
0
5 000
10 000
15 000
20 000
25 000
30 000
Burnup [MWd/t]
172-172
172-69
172-7
172-6
172-nobe
281-281
281-69
281-7
281-6
281-nobe

RESULTS

Cold conditions

	Keff	Δkeff [pcm]
APOLLO2	1.69860	
TRIPOLI4	1.70989	389
SERPENT	1.69498	-126
MCNP	1.70148	101

RESULTS



Keff
1,70E+00
1,65E+00
1,60E+00
1,55E+00
1,50E+00
1,45E+00
Keff
APOLLO2
SERPENT burnsteps
time
1
0,5
0
1
5001
10001
15001
20001
25001
30001
Burnup [MWd/t]

SUMMARY

- Good agreement for both APOLLO2 methods
- TRIPOLI4 results are acceptable but with relatively high discrepancy
- TRIPOLI4 is not designed to calculate burnup
- SERPENT calculations are promising but need improvement

THANK YOU!