

1 OECD/NEA Benchmark

Figure 1 Table 1 Figure 2 Figure 3

6978218 Dofs Dofs/Group = 268393 time (1024 cores) = 4.33 and 4.11 hours

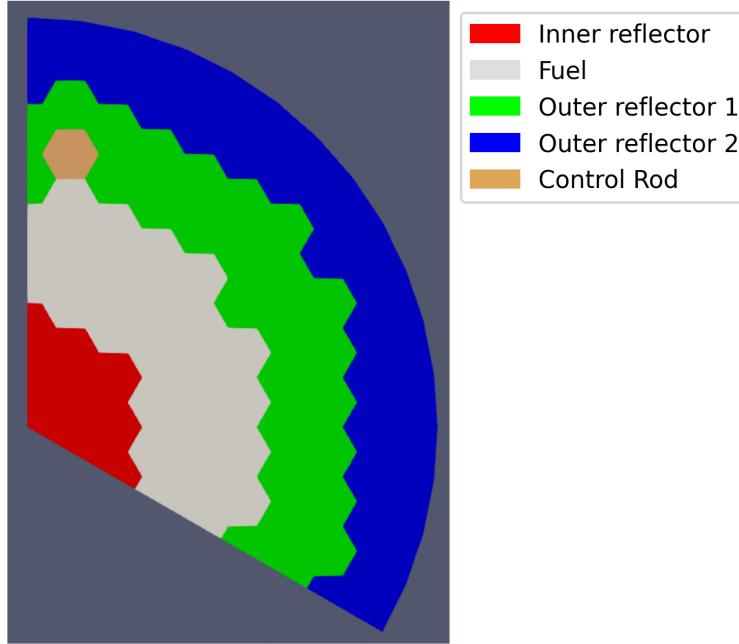


Figure 1: 1/3rd MHTGR-350 geometry.

Table 1: Global parameters.

Parameter	Benchmark	Moltres
K_{eff}	1.06691	1.06804
$\Delta\rho_{CR}$ (pcm)	822.1	509.8
AO	0.168	0.1753

1.1 Periodic vs Neumann BCs

Table 2

3G) 62118 dofs/group = 186354 dofs

6G) 16898 dofs/group = 101388 dofs

Table 2: Global parameters comparison for different types of BCs.

Energy groups	Type of BCs	$K_{eff,out}$	$K_{eff,in}$	$\Delta\rho_{CR}$ (pcm)	AO
3	Periodic	1.07571	1.06776	692.6	0.237
	Neumann	1.07586	1.07021	490.5	0.237
6	Periodic	1.07182	1.06356	724.3	0.185
	Neumann	1.07197	1.06610	513.3	0.186

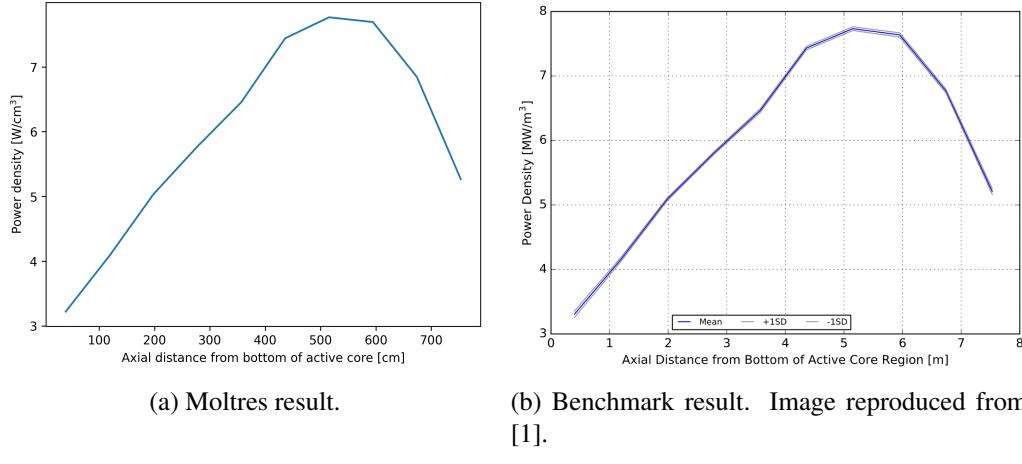


Figure 2: Radially averaged axial power distribution.

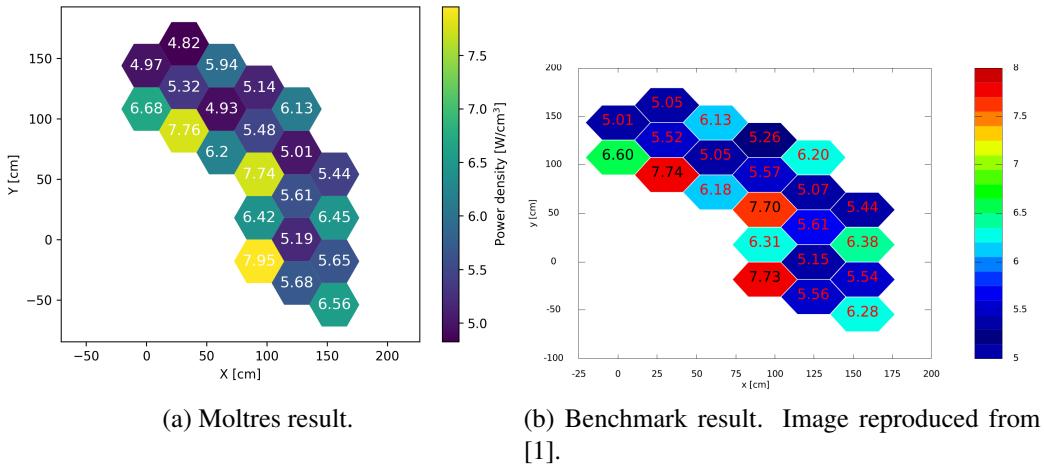


Figure 3: Axially averaged radial power distribution.

2 Assembly

Moltres DOFs: N of elements: 37120 Nodes (DOFs/group): 22862

Serpent Keff: noLBP-600: 1.43800 noLBP-1200: 1.37771 LBP-600: 1.12861 LBP-1200: 1.06554

Table 3

Figure 5 Figure 6

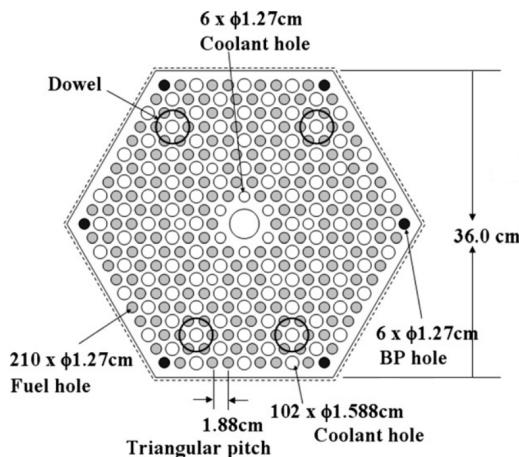
Figure 7 Figure 8

Figure 9 Figure 10

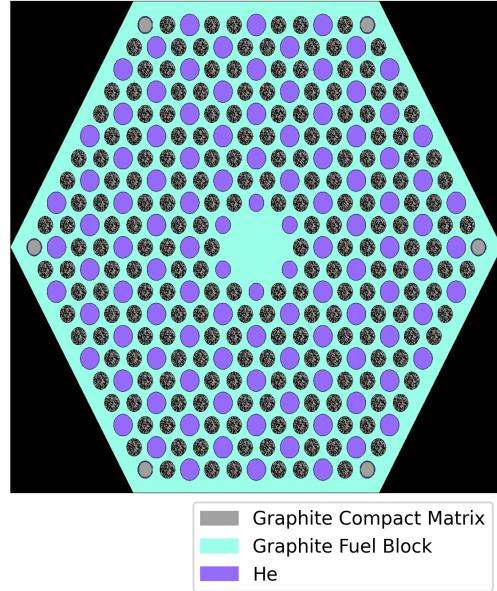
Figure 11 Figure 12

Figure 13

Table 4

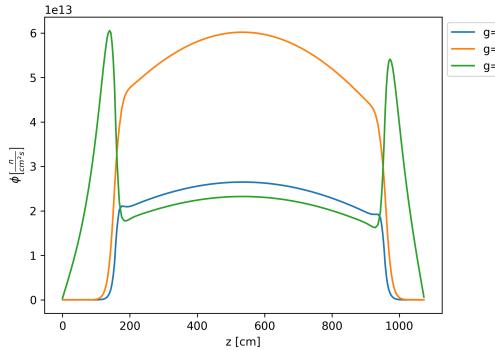


(a) Fuel column geometry. Image reproduced from [2].

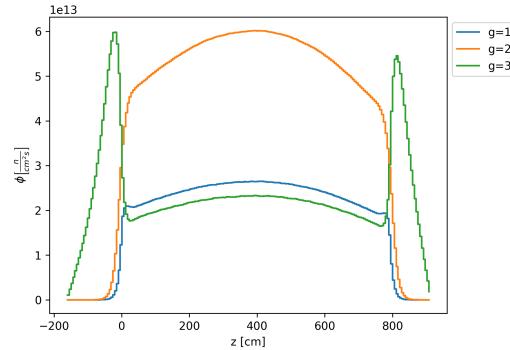


(b) Serpent model geometry.

Figure 4: Fuel column of the MHTGR-350. XY-plane in the active core region.



(a) Moltres.



(b) Serpent.

Figure 5: Axial neutron flux for 3 groups.

Table 3: Energy group structure.

Upper boundary [eV]	26	21	18	15a	15b	15c	15d	15e	12	9	6	3
1.49E+07	1	1	1	1	1	1	1	1	1	1	1	1
7.41E+06	2											
3.68E+06	3	2	2	2	2	2	2	2	2			
6.72E+05	4											
1.11E+05	5	3	3	3	3					2	2	2
1.93E+04	6	4	4	4	4					4		
3.35E+03	7											
1.58E+03	8	5	5									
7.48E+02	9	6	6	5	5					5	3	
2.75E+02	10	7	7	6	6					6	4	
1.30E+02	11	8	8	7	7					7	5	3
6.14E+01	12	9										
2.90E+01	13	10	9	8								
1.37E+01	14	11	10	9							8	6
8.32E+00	15	12	11	10						9		
5.04E+00	16											
2.38E+00	17	13								10	7	4
1.29E+00	18	14										
6.50E-01	19	15								11	8	5
3.50E-01	20	16										
2.00E-01	21	17										
1.20E-01	22											
8.00E-02	23	18	15									
5.00E-02	24	19	16									
2.00E-02	25	20	17							12	9	6
1.00E-02	26	21	18									

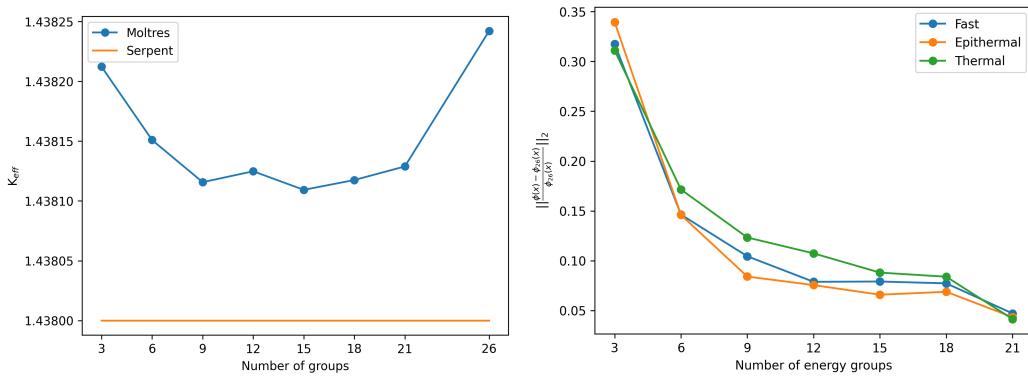


Figure 6: Effect of different number of energy group structures over different parameters.

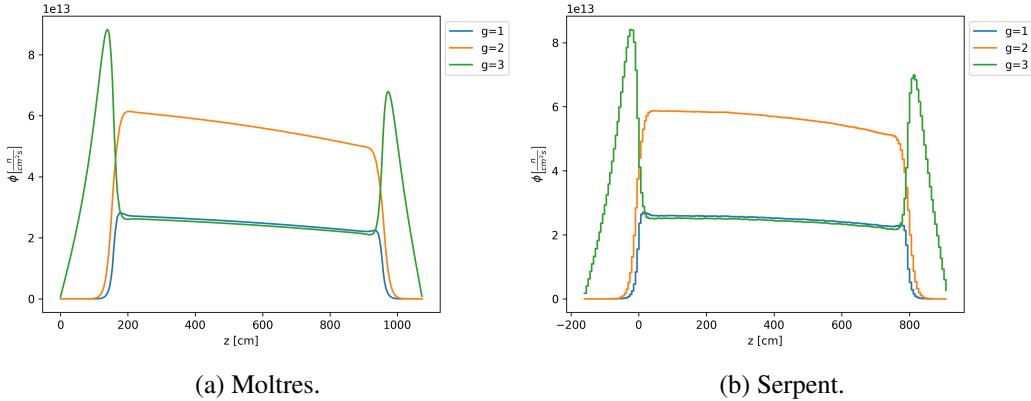


Figure 7: Axial neutron flux for 3 groups.

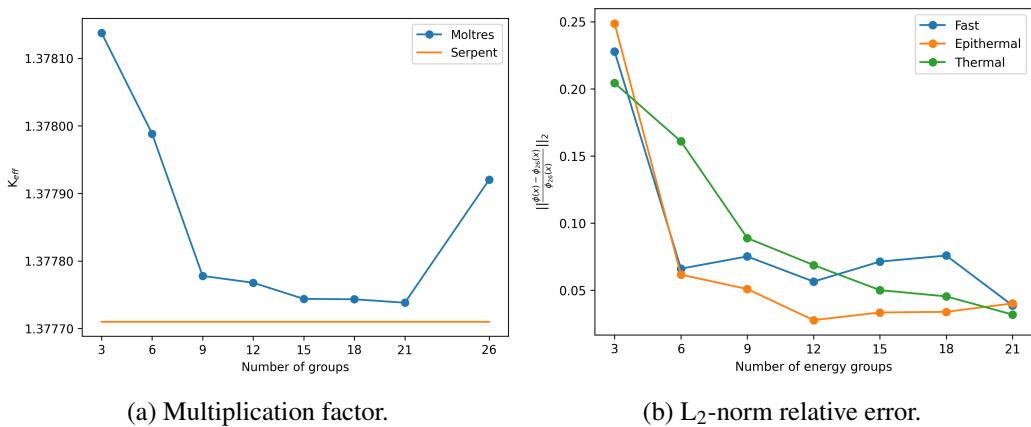


Figure 8: Effect of different number of energy group structures over different parameters.

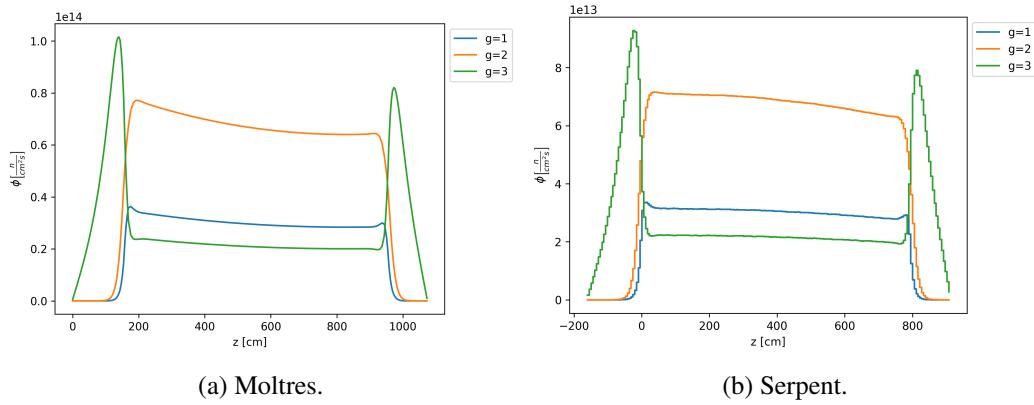


Figure 9: Axial neutron flux for 3 groups.

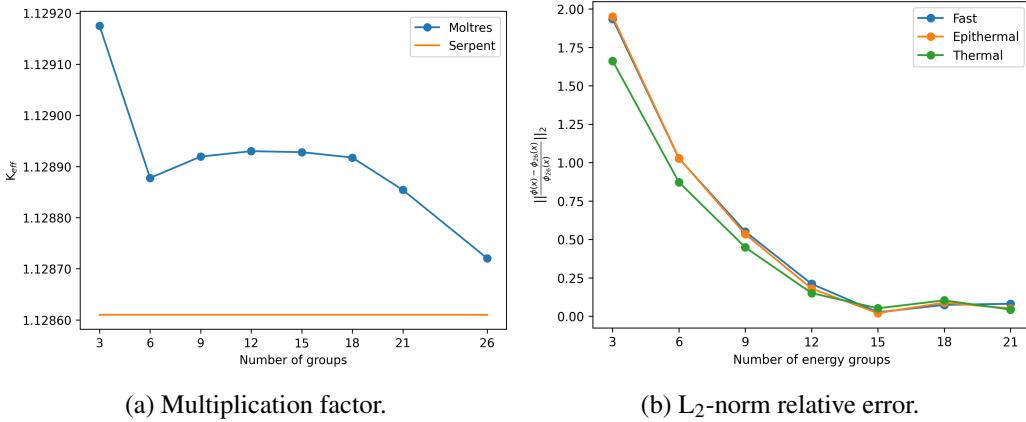


Figure 10: Effect of different number of energy group structures over different parameters.

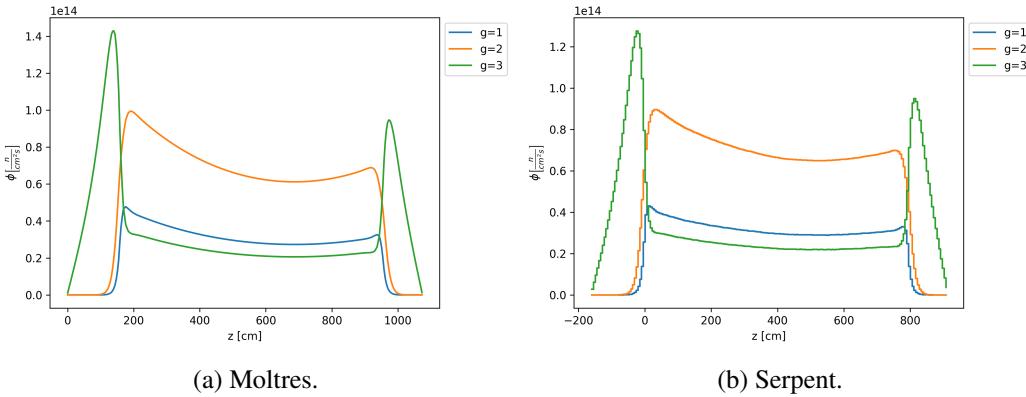


Figure 11: Axial neutron flux for 3 groups.

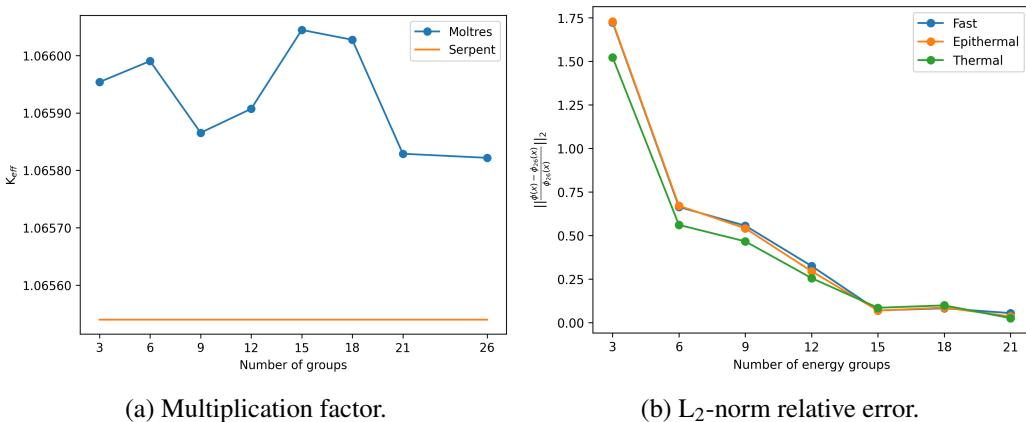


Figure 12: Effect of different number of energy group structures over different parameters.

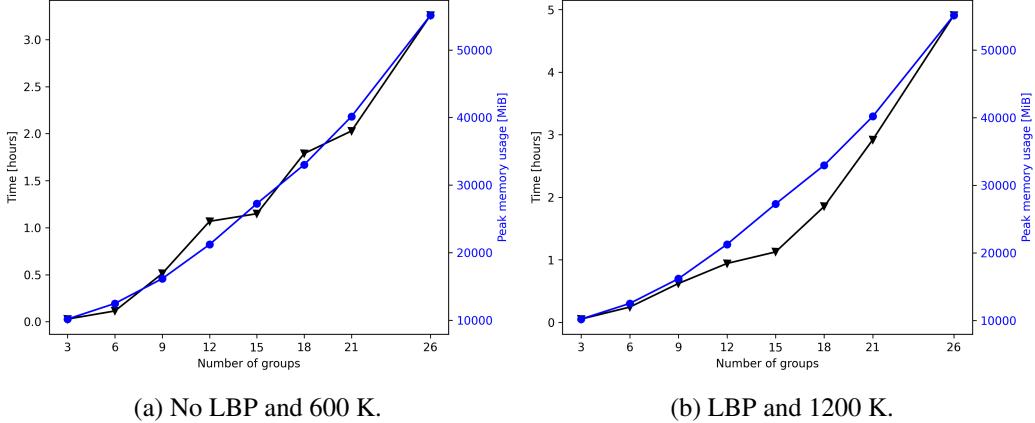


Figure 13: Effect of different number of energy group structures over computational time and memory requirements.

Table 4: Parametric study on the energy group limits. Values expressed in percentage.

LBP	Temperature [K]	Flux	15a	15b	15c	15d	15e
No	600	Fast	7.9	8.0	8.2	8.1	9.1
		Epithermal	6.6	6.5	8.6	8.2	9.2
		Thermal	8.8	8.5	10.6	10.7	12.9
	1200	Fast	7.1	7.7	5.7	5.1	4.5
		Epithermal	3.3	3.9	6.2	5.1	3.4
		Thermal	5.0	4.7	8.5	8.2	8.4
Yes	600	Fast	24.0	24.8	2.6	2.3	3.7
		Epithermal	21.0	21.7	2.0	1.6	2.7
		Thermal	18.1	18.8	5.2	5.5	5.7
	1200	Fast	36.2	37.3	6.9	6.6	25.9
		Epithermal	33.2	34.2	6.9	6.5	25.1
Average			17.3	17.8	6.3	6.0	10.8

3 Fullcore

Dof/group = 160035 total dof = 2400525

Serpent: keff (600K) = 1.10869 keff (1200K) = 1.06138

Moltres: keff (600K) = 1.1115000683 keff (1200K) = 1.0646803289

Figure 14

Figure 15 Figure 16

Figure 17

Figure 18 Figure 19 Figure 20

Figure 21 Figure 22 Figure 23

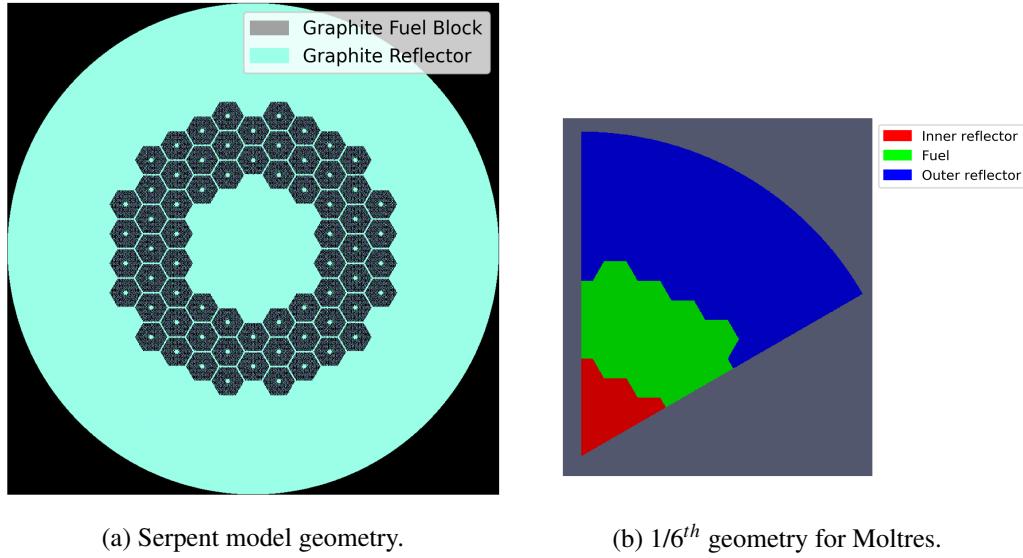


Figure 14: MHTGR-350 full core models.

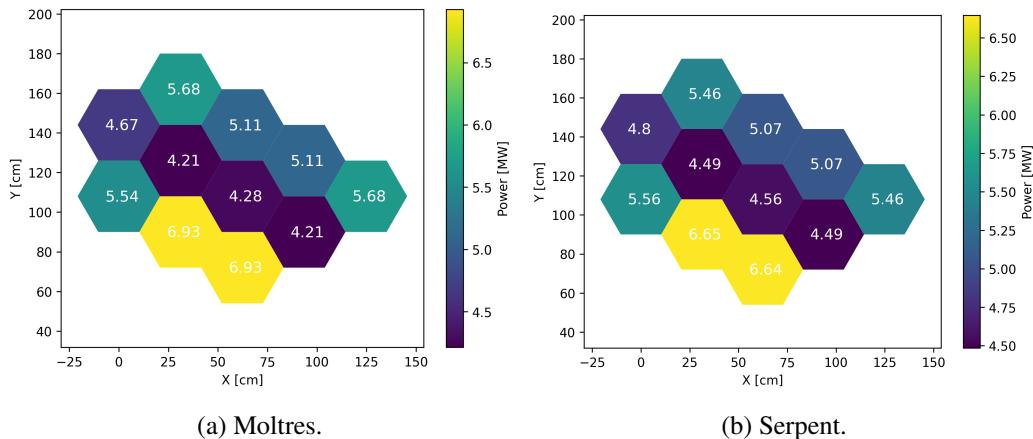
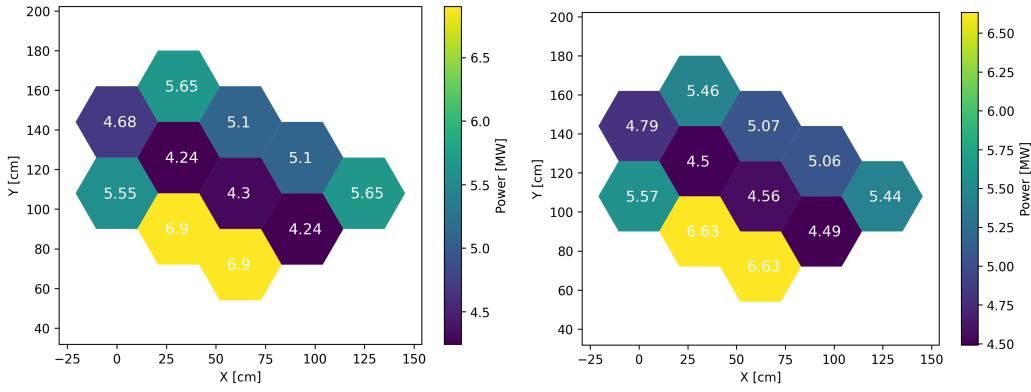


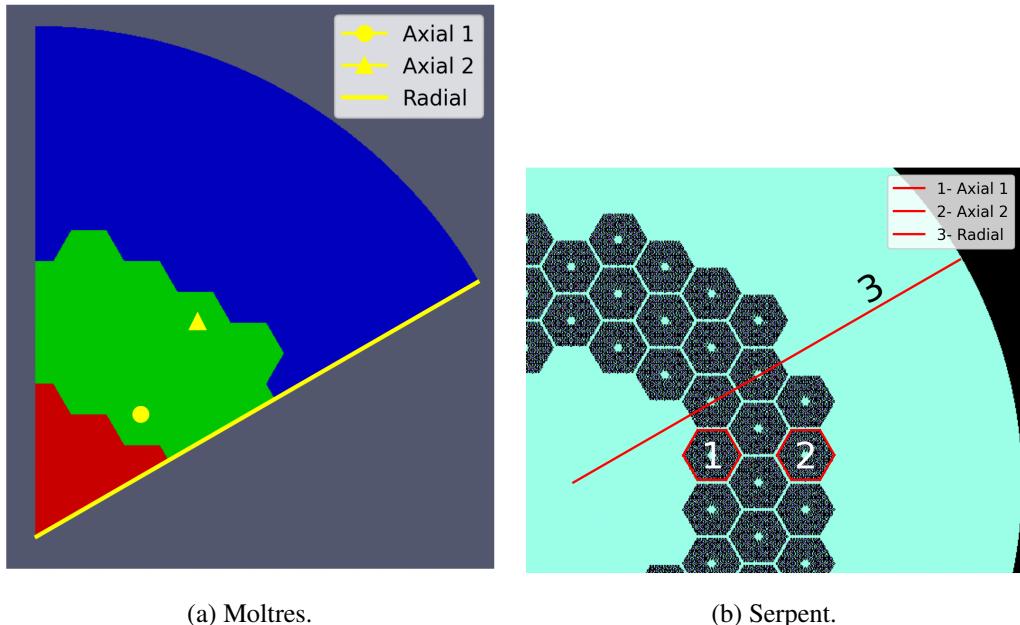
Figure 15: Radial power distribution at 600 K.



(a) Moltres.

(b) Serpent.

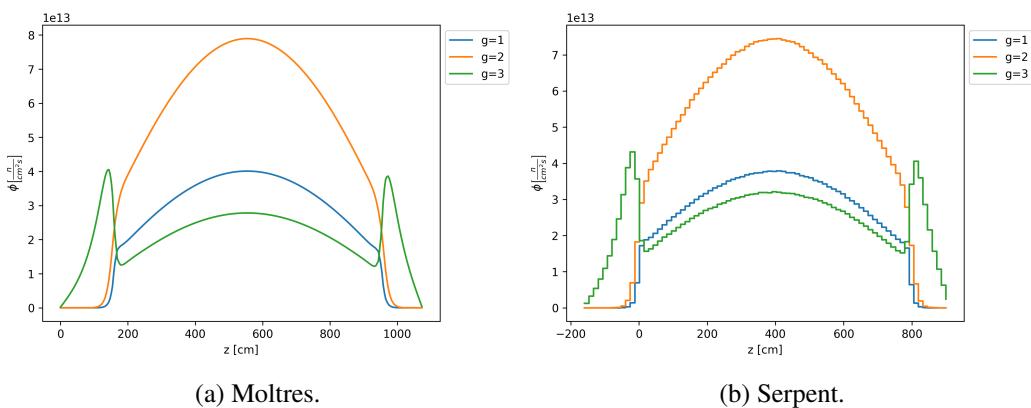
Figure 16: Radial power distribution.



(a) Moltres.

(b) Serpent.

Figure 17: Flux detector locations.



(a) Moltres.

(b) Serpent.

Figure 18: Flux in axial detector 1 at 600 K.

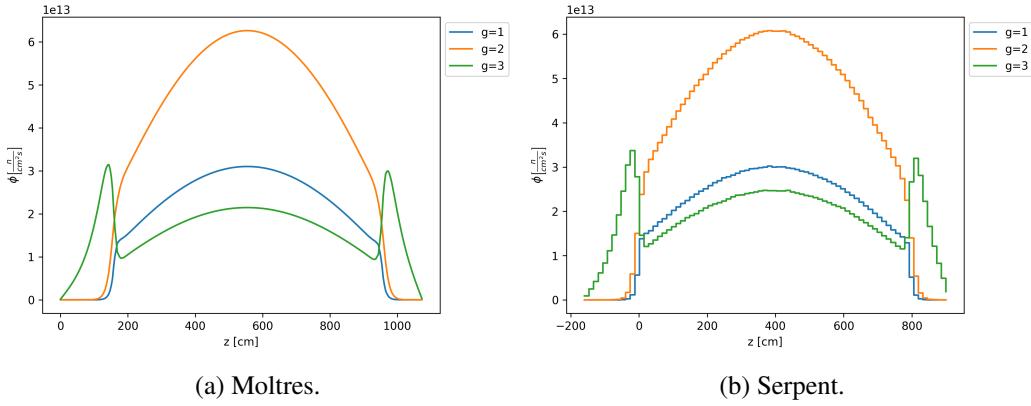


Figure 19: Flux in axial detector 2 at 600 K.

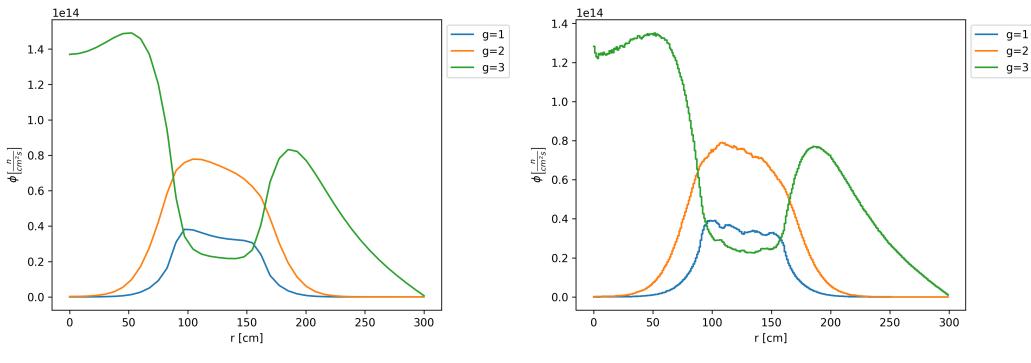


Figure 20: Radial flux at 600 K

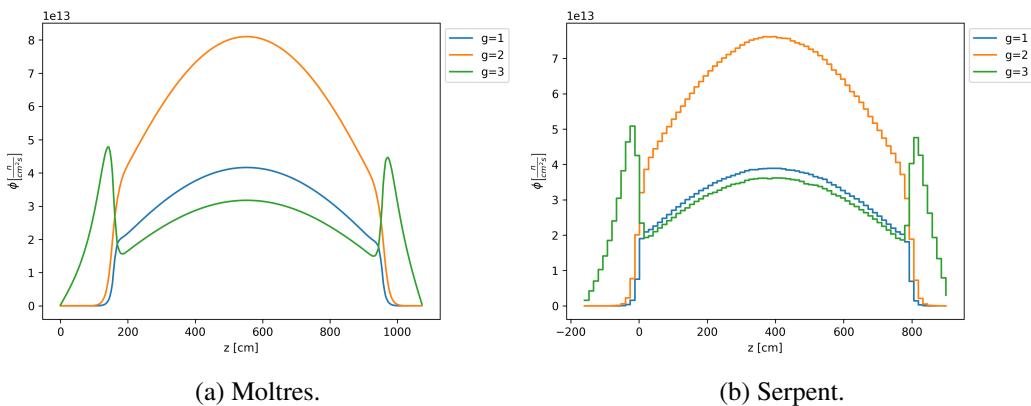


Figure 21: Flux in axial detector 1 at 1200 K.

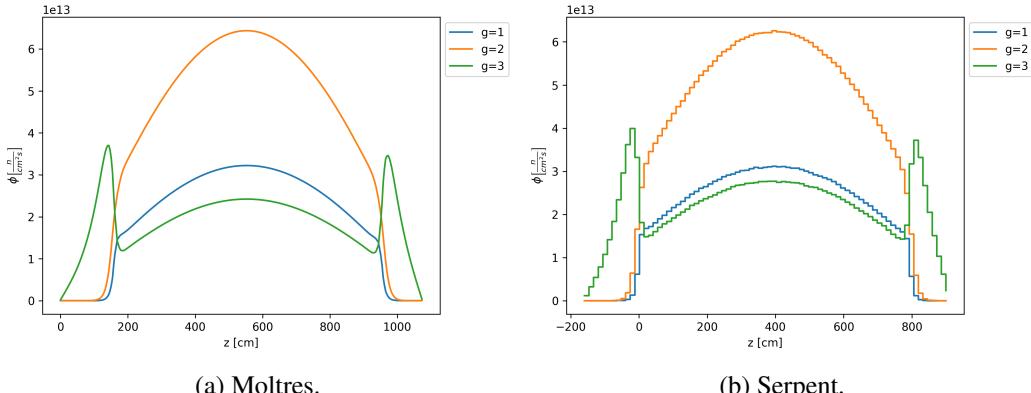


Figure 22: Flux in axial detector 2 at 1200 K.

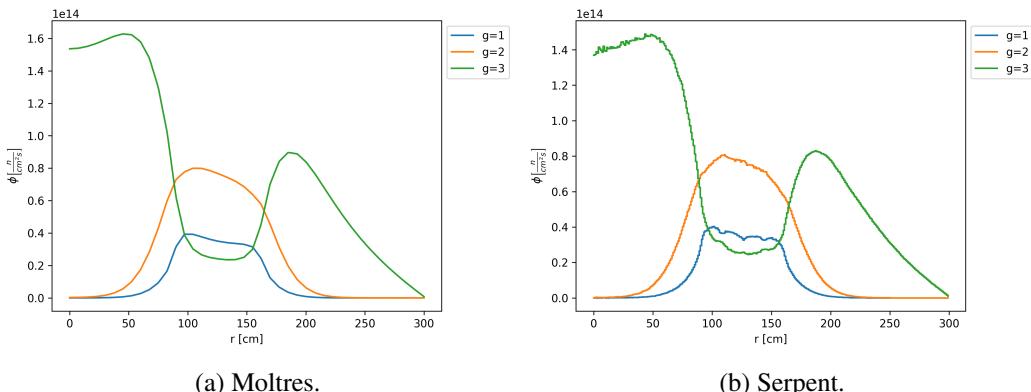


Figure 23: Radial flux at 1200 K.

References

- [1] OECD NEA. Coupled Neutronic/Thermal- Fluid Benchmark of the MHTGR-350 MW Core Design: Results for Phase I Exercise 1, February 2020.
- [2] Nam-il Tak, Min-Hwan Kim, and Won Jae Lee. Numerical investigation of a heat transfer within the prismatic fuel assembly of a very high temperature reactor. *Annals of Nuclear Energy*, 35(10):1892–1899, October 2008.