Karlsruher Institut für Technologie

Using the NEMTAB XS libraries from the Oskarshamn-2 Benchmark with DYN3D

J. Vargas, J. Jiménez, v. Sanchez

Institute for Neutron Physics and Reactor Technology (INR)

Reactor Physics and Dynamic Group (RPD)

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- Neutron Kinetic Core Model: DYN3D
- Current status
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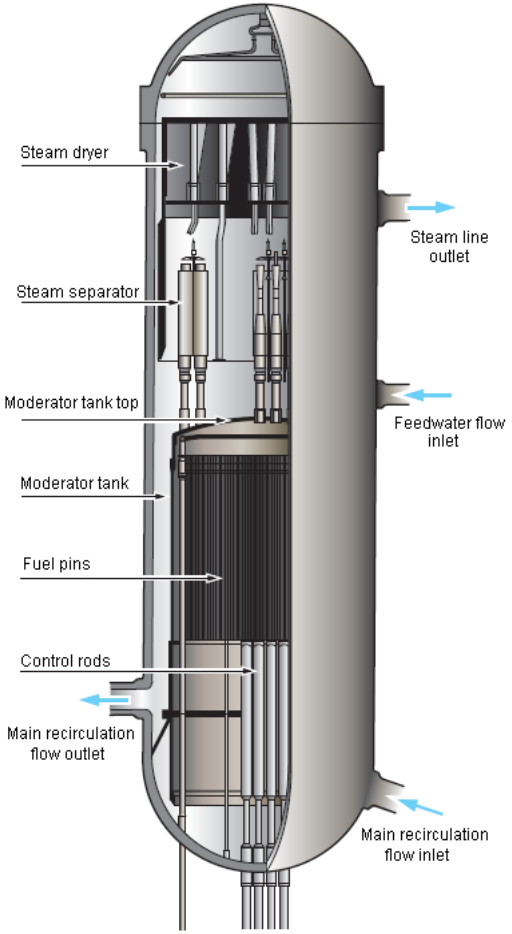
O2 BWR ABB-Atom Design: Data

O2 RPV and Core Loading for Cycle 24



Oskarshamn-2 RPV

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
2	0	0	0	1	1	13	14	15	15	15	15	15	15	15	14	15	15	14	15	1	1	0	0	0
3	0	0	1	1	15	16	16	17	17	17	15	14	17	17	16	17	16	17	15	13	1	1	0	0
4	0	1	1	14	13	17	21	17	20	20	16	20	20	20	20	20	17	20	17	14	16	1	1	0
5	1	1	13	13	20	20	16	21	23	17	21	16	23	21	17	23	16	17	20	20	13	14	1	1
6	1	15	17	20	20	16	23	20	16	21	20	21	17	16	21	16	21	23	14	20	20	17	15	1
7	1	15	17	20	15	23	21	13	16	20	21	16	21	21	13	20	17	21	23	16	21	15	13	1
8	1	15	13	17	20	21	17	23	18	18	18	20	18	18	16	16	21	16	20	21	20	13	15	1
9	1	15	17	22	23	16	21	17	21	18	18	18	21	21	16	21	15	21	15	23	20	13	15	1
10	1	15	16	22	17	21	18	21	15	17	17	21	18	20	20	18	18	20	20	16	20	16	15	1
11	1	15	16	17	20	16	21	16	21	20	21	18	20	21	19	18	18	21	16	21	20	17	14	1
12	1	15	16	16	23	17	21	16	21	19	20	18	18	18	20	16	16	16	21	16	20	16	15	1
13	1	15	16	20	16	21	16	16	16	20	18	18	18	20	19	21	16	21	17	23	16	16	15	1
14	1	14	17	20	21	16	21	18	18	19	21	20	18	21	20	21	16	21	16	20	17	16	15	1
15	1	15	16	20	16	20	20	18	18	20	20	18	21	17	17	15	21	18	21	17	22	16	15	1
16	1	15	13	20	23	15	21	15	21	16	21	21	18	18	18	21	17	21	16	23	22	17	15	1
17	1	15	13	20	21	20	16	21	16	16	18	18	20	18	18	18	23	17	21	20	17	13	15	1
18	1	13	15	21	16	23	21	17	20	13	21	21	16	21	20	16	13	21	23	15	20	17	15	1
19	1	15	17	20	20	14	23	21	16	21	16	17	21	20	21	16	20	23	16	20	20	17	15	1
20	1	1	14	13	20	20	17	16	23	17	21	23	16	21	17	23	21	16	20	20	13	13	1	1
21	0	1	1	16	14	17	20	17	20	20	20	20	20	16	20	20	17	21	17	13	14	1	1	0
22	0	0	1	1	13	15	17	16	17	16	17	17	14	15	17	17	17	16	16	15	1	1	0	0
23	0	0	0	1	1	15	14	15	15	14	15	15	15	15	15	15	15	14	13	1	1	0	0	0
24	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0

FA type		Amount
REF	1	
SO	13	24
SP	14	18
SQ	15	60
SR	16	72
SS	17	58
QA	18	36
QB	19	4
QC	20	76
QD	21	70
LT	22	4
QE	23	22
Total FA		444

O2 Core: Radial distribution of the FA-Types

Neutron Kinetic Core Model: DYN3D

XS library specifications

- The CASMO code was applied to generate the 2-group macroscopic cross-sections needed for DYN3D calculations.
- The burnup and the historical parameters are implicitly included in the macroscopic cross-section. 25 axial nodes in the active core are used.
- Fifteen branching points for the moderator density are selected. They range from the core inlet density up to the minimum core exit density (in kg/m^3):

  176.68, 177.44, 177.53, 317.95, 330.85,

  341.59, 458.37, 485.01, 505.74, 598.79,

  639.18, 669.89, 739.20, 793.35, 834.04.
- Eight fuel temperature branching points are selected (in K):

  500, 650, 800, 950,1100, 1250, 1400, and 1550.

XS library specifications

- The half core rotational symmetry is used to limit the number of materials therefore leading to a total of different fuel materials of 444/2 * 25 (rodded) + 444/2 *25 (unrodded) + 3 reflector = 11103 XS sets.
- The XS library is given in 2G NEMTAB format:
  - Diffusion coefficient
  - Absorption cross-section
  - Fission cross-section
  - Nu-fission cross-section
  - Scattering cross-section (only from group 1 to group 2)
  - ADF-West
  - ADF-South
  - Macroscopic Xe cross-section (only for group 2)
  - Microscopic Xe cross-section (only for group 2)

O2 Core loading according to the XS library

- In the XS library, 11103 different materials compositions are defined which correspond to 445 (222+1+222) sets of fuel assemblies, they are classified as follow:
  - Fuel Assemblies from 1 to 222 → unrodded, material from 1 to 5550
  - Fuel Assembly 223→ radial reflector, materials 5551, 5552 and 5553
  - Fuel Assemblies from 224 to 445 → rodded, materials from 5554 to 11103

				223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				
			223	223	1	2	3	4	5	6	7	222	221	220	219	218	217	216	223	223			
		223	223	8	9	10	11	12	13	14	15	215	214	213	212	211	210	209	208	223	223		
	223	223	16	17	18	19	20	21	22	23	24	207	206	205	204	203	202	201	200	199	223	223	
223	223	25	26	27	28	29	30	31	32	33	34	198	197	196	195	194	193	192	191	190	189	223	223
223	35	36	37	38	39	40	41	42	43	44	45	188	187	186	185	184	183	182	181	180	179	178	223
223	46	47	48	49	50	51	52	53	54	55	56	177	176	175	174	173	172	171	170	169	168	167	223
223	57	58	59	60	61	62	63	64	65	66	67	166	165	164	163	162	161	160	159	158	157	156	223
223	68	69	70	71	72	73	74	75	76	77	78	155	154	153	152	151	150	149	148	147	146	145	223
223	79	80	81	82	83	84	85	86	87	88	89	144	143	142	141	140	139	138	137	136	135	134	223
223	90	91	92	93	94	95	96	97	98	99	100	133	132	131	130	129	128	127	126	125	124	123	223
223	101	102	103	104	105	106	107	108	109	110	111	122	121	120	119	118	117	116	115	114	113	112	223
223	112	113	114	115	116	117	118	119	120	121	122	111	110	109	108	107	106	105	104	103	102	101	223
223	123	124	125	126	127	128	129	130	131	132	133	100	99	98	97	96	95	94	93	92	91	90	223
223	134	135	136	137	138	139	140	141	142	143	144	89	88	87	86	85	84	83	82	81	80	79	223
223	145	146	147	148	149	150	151	152	153	154	155	78	77	76	75	74	73	72	71	70	69	68	223
223	156	157	158	159	160	161	162	163	164	165	166	67	66	65	64	63	62	61	60	59	58	57	223
223	167	168	169	170	171	172	173	174	175	176	177	56	55	54	53	52	51	50	49	48	47	46	223
223	178	179	180	181	182	183	184	185	186	187	188	45	44	43	42	41	40	39	38	37	36	35	223
223	223	189	190	191	192	193	194	195	196	197	198	34	33	32	31	30	29	28	27	26	25	223	223
	223	223	199	200	201	202	203	204	205	206	207	25	23	22	21	20	19	18	17	16	223	223	
		223	223	208	209	210	211	212	213	214	215	15	14	13	12	11	10	9	8	223	223		
			223	223	216	217	218	219	220	221	222	7	6	5	4	3	2	1	223	223			
				223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				

O2 Core loading according to the XS library

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Composition # Axial Layer unrodded

	1	2	3	4	5	···	222	223
1	5551	5551	5551	5551	5551	···	5551	5551
2	1	26	51	76	101	···	5526	5552
3	2	27	52	77	102	···	5527	5552
4	3	28	53	78	103	···	5528	5552
5	4	29	54	79	104	···	5529	5552
6	5	30	55	80	105	···	5530	5552
7	6	31	56	81	106	···	5531	5552
8	7	32	57	82	107	···	5532	5552
9	8	33	58	83	108	···	5533	5552
10	9	34	59	84	109	···	5534	5552
11	10	35	60	85	110	···	5535	5552
12	11	36	61	86	111	···	5536	5552
13	12	37	62	87	112	···	5537	5552
14	13	38	63	88	113	···	5538	5552
15	14	39	64	89	114	···	5539	5552
16	15	40	65	90	115	···	5540	5552
17	16	41	66	91	116	···	5541	5552
18	17	42	67	92	117	···	5542	5552
19	18	43	68	93	118	···	5543	5552
20	19	44	69	94	119	···	5544	5552
21	20	45	70	95	120	···	5545	5552
22	21	46	71	96	121	···	5546	5552
23	22	47	72	97	122	···	5547	5552
24	23	48	73	98	123	···	5548	5552
25	24	49	74	99	124	···	5549	5552
26	25	50	75	100	125	···	5550	5552
27	5553	5553	5553	5553	5553	···	5553	5553

Bottom Reflector

11,96
31,33
46,18
61,03
75,88
90,73
105,57
120,42
135,27
150,12
164,97
179,81
194,66
209,51
224,36
239,21
254,05
268,9
283,75
298,6
313,45
328,29
343,14
357,99
372,84
387,69
414,19

Top Reflector

Composition # Axial Layer rodded

	1	2	3	4	5	···	222	223
1	5551	5551	5551	5551	5551	···	5551	5551
2	5554	5579	5604	5629	5654	···	11079	5552
3	5555	5580	5605	5630	5655	···	11080	5552
4	5556	5581	5606	5631	5656	···	11081	5552
5	5557	5582	5607	5632	5657	···	11082	5552
6	5558	5583	5608	5633	5658	···	11083	5552
7	5559	5584	5609	5634	5659	···	11084	5552
8	5560	5585	5610	5635	5660	···	11085	5552
9	5561	5586	5611	5636	5661	···	11086	5552
10	5562	5587	5612	5637	5662	···	11087	5552
11	5563	5588	5613	5638	5663	···	11088	5552
12	5564	5589	5614	5639	5664	···	11089	5552
13	5565	5590	5615	5640	5665	···	11090	5552
14	5566	5591	5616	5641	5666	···	11091	5552
15	5567	5592	5617	5642	5667	···	11092	5552
16	5568	5593	5618	5643	5668	···	11093	5552
17	5569	5594	5619	5644	5669	···	11094	5552
18	5570	5595	5620	5645	5670	···	11095	5552
19	5571	5596	5621	5646	5671	···	11096	5552
20	5572	5597	5622	5647	5672	···	11097	5552
21	5573	5598	5623	5648	5673	···	11098	5552
22	5574	5599	5624	5649	5674	···	11099	5552
23	5575	5600	5625	5650	5675	···	11100	5552
24	5576	5601	5626	5651	5676	···	11101	5552
25	5577	5602	5627	5652	5677	···	11102	5552
26	5578	5603	5628	5653	5678	···	11103	5552
27	5553	5553	5553	5553	5553	···	5553	5553

Geometry definition

- The radial node width is assumed to be 15.275 cm.
- The active core height is 371.2 cm and is uniformly divided into 25 segments of 14.848 cm each.
- As far as the homogenization is concerned:
  - The active core starts from node 2 end ends in node 26
  - Node 1 is the bottom reflector
  - Node 27 is the top reflector
- Bottom reflector has 23.91 cm and a top reflector 38.15 cm

CR Bank definition

- In the Oskarshamn-2 power plant the control rods are grouped in 19 banks

	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
-12					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
-11				0	0	13	13	14	14	17	17	10	10	11	11	14	14	15	15	0	0			
-10			0	0	0	13	13	14	14	17	17	10	10	11	11	14	14	15	15	0	0	0		
-9		0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	9	9	0	0	
-8	0	0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	9	9	0	0	0
-7	0	11	11	12	12	15	15	16	16	9	9	12	12	13	13	16	16	17	17	12	12	11	11	0
-6	0	11	11	12	12	15	15	16	16	9	9	12	12	13	13	16	16	17	17	12	12	11	11	0
-5	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
-4	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
-3	0	9	9	14	14	13	13	10	10	17	17	14	14	11	11	19	19	15	15	14	14	13	13	0
-2	0	9	9	14	14	13	13	10	10	17	17	14	14	11	11	19	19	15	15	14	14	13	13	0
-1	0	4	4	1	1	2	2	7	7	8	8	18	18	6	6	3	3	4	4	1	1	2	2	0
0	0	4	4	1	1	2	2	7	7	8	8	18	18	6	6	3	3	4	4	1	1	2	2	0
1	0	15	15	16	16	11	11	19	19	15	15	16	16	9	9	12	12	17	17	16	16	11	11	0
2	0	15	15	16	16	11	11	19	19	15	15	16	16	9	9	12	12	17	17	16	16	11	11	0
3	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
4	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
5	0	9	9	10	10	17	17	14	14	13	13	10	10	11	11	14	14	13	13	10	10	9	9	0
6	0	9	9	10	10	17	17	14	14	13	13	10	10	11	11	14	14	13	13	10	10	9	9	0
7	0	0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	1	1	0	0	0
8		0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	1	1	0	0	
9			0	0	0	15	15	16	16	9	9	12	12	17	17	16	16	15	15	0	0	0		
10				0	0	15	15	16	16	9	9	12	12	17	17	16	16	15	15	0	0			
11					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

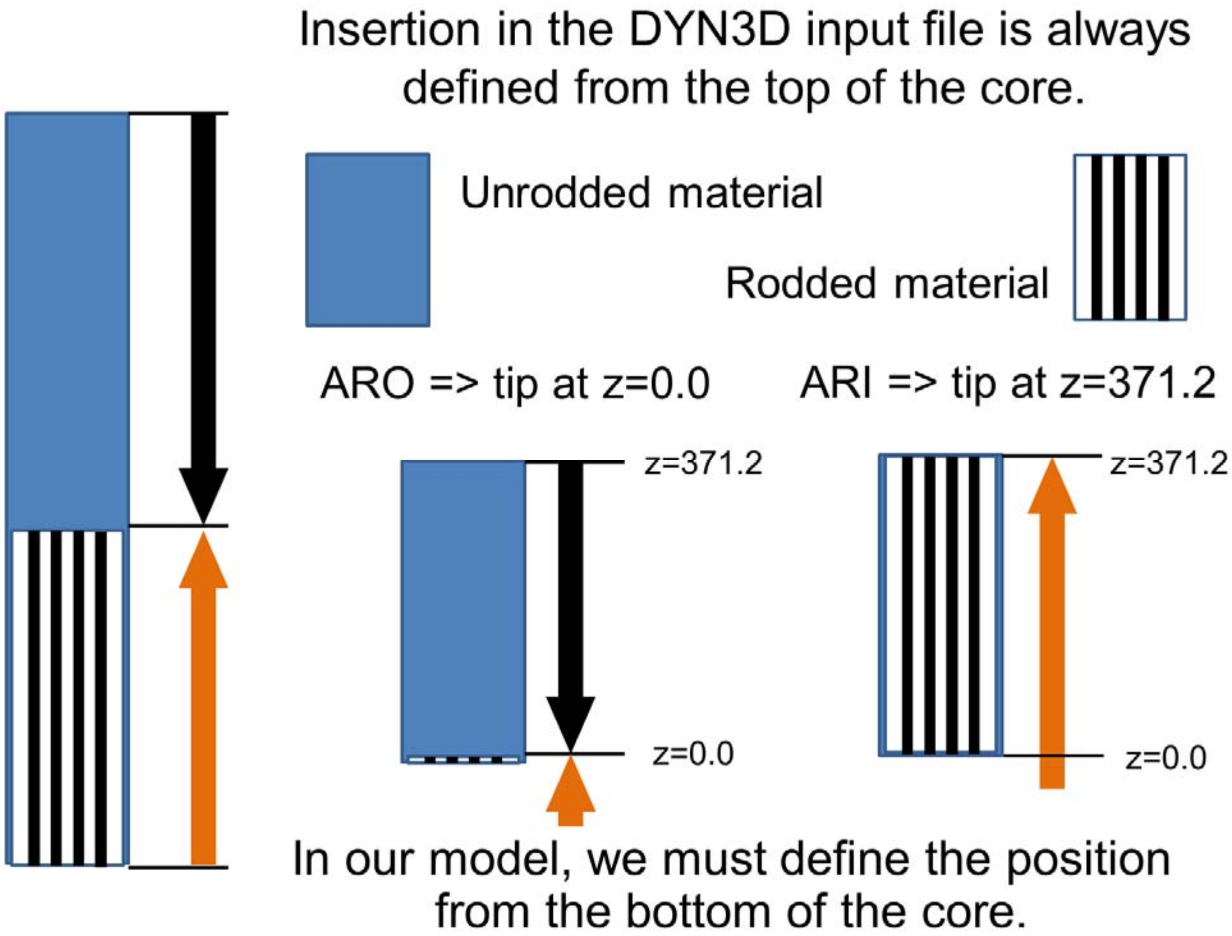
CR Bank definition

- The material composition of the fuel unrodded assemblies

	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
-12					223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				
-11				223	223	224	225	226	227	228	229	230	445	444	443	442	441	440	439	223	223			
-10			223	223	231	232	233	234	235	236	237	238	438	437	436	435	434	433	432	431	223	223		
-9		223	223	239	240	241	242	243	244	245	246	247	430	429	428	427	426	425	424	423	422	223	223	
-8	223	223	248	249	250	251	252	253	254	255	256	257	421	420	419	418	417	416	415	414	413	412	223	223
-7	223	258	259	260	261	262	263	264	265	266	267	268	411	410	409	408	407	406	405	404	403	402	401	223
-6	223	269	270	271	272	273	274	275	276	277	278	279	400	399	398	397	396	395	394	393	392	391	390	223
-5	223	280	281	282	283	284	285	286	287	288	289	290	389	388	387	386	385	384	383	382	381	380	379	223
-4	223	291	292	293	294	295	296	297	298	299	300	301	378	377	376	375	374	373	372	371	370	369	368	223
-3	223	302	303	304	305	306	307	308	309	310	311	312	367	366	365	364	363	362	361	360	359	358	357	223
-2	223	313	314	315	316	317	318	319	320	321	322	323	356	355	354	353	352	351	350	349	348	347	346	223
-1	223	324	325	326	327	328	329	330	331	332	333	334	345	344	343	342	341	340	339	338	337	336	335	223
0	223	335	336	337	338	339	340	341	342	343	344	345	334	333	332	331	330	329	328	327	326	325	324	223
1	223	346	347	348	349	350	351	352	353	354	355	356	323	322	321	320	319	318	317	316	315	314	313	223
2	223	357	358	359	360	361	362	363	364	365	366	367	312	311	310	309	308	307	306	305	304	303	302	223
3	223	368	369	370	371	372	373	374	375	376	377	378	301	300	299	298	297	296	295	294	293	292	291	223
4	223	379	380	381	382	383	384	385	386	387	388	389	290	289	288	287	286	285	284	283	282	281	280	223
5	223	390	391	392	393	394	395	396	397	398	399	400	279	278	277	276	275	274	273	272	271	270	269	223
6	223	401	402	403	404	405	406	407	408	409	410	411	268	267	266	265	264	263	262	261	260	259	258	223
7	223	223	412	413	414	415	416	417	418	419	420	421	257	256	255	254	253	252	251	250	249	248	223	223
8		223	223	422	423	424	425	426	427	428	429	430	248	246	245	244	243	242	241	240	239	223	223	
9			223	223	431	432	433	434	435	436	437	438	238	237	236	235	234	233	232	231	223	223		
10				223	223	439	440	441	442	443	444	445	230	229	228	227	226	225	224	223	223			
11					223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				

Control rod position

- For modeling CR entering from the bottom of the core with DYN3D



Preliminary Steady State Results obtained with DYN3D

Considered Cases

- Objective: Checking the XS library by inserting the CR Banks at 5 different elevations, considering 5 different cases.
- DYN3D is coupled with FLOCAL

Case 1

- Oskarshamn-2 input deck with XS library given by Benchmark organizers.

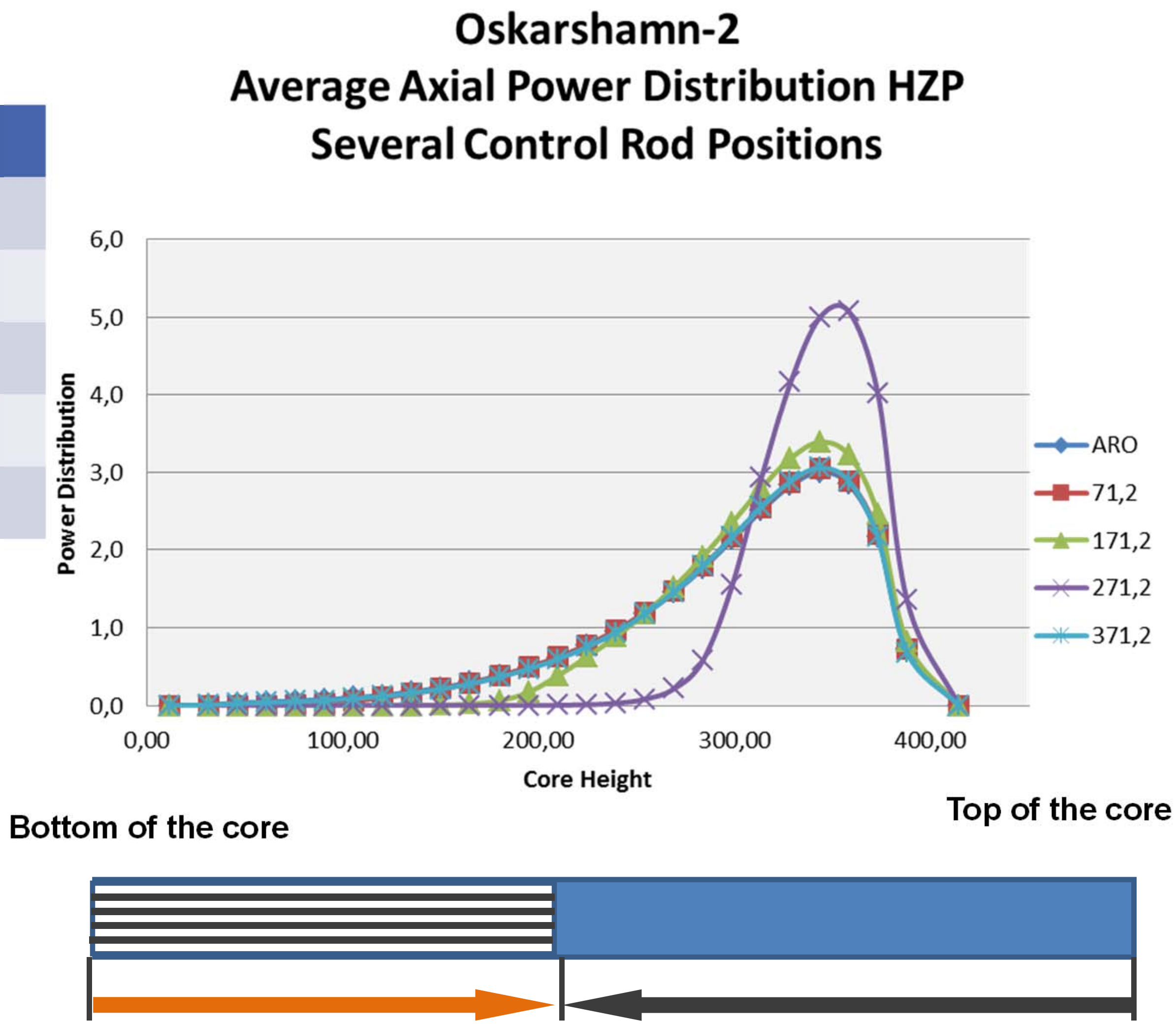
Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.014586	NaN
71.2	1.14575	NaN
171.2	1.014196	NaN
271.2	1.004227	NaN
371.2 (ARI)	0.796669	NaN

Calc. Failed

Case 1

- Power is very much displaced to the top of the core

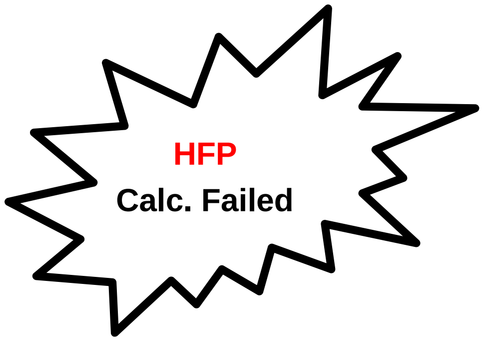
Elevation	Keff HZP
0.0 (ARO)	1.014586
71.2	1.14575
171.2	1.014196
271.2	1.004227
371.2 (ARI)	0.796669

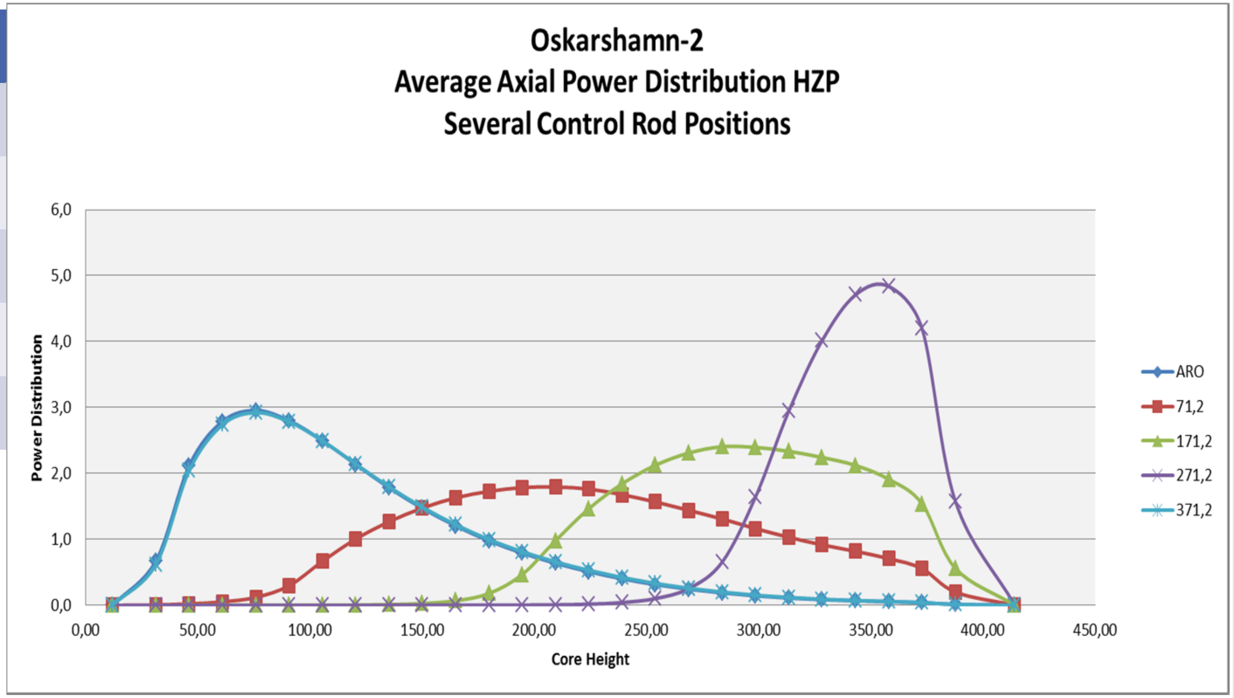


Case 2

- Oskarshamn-2 input deck with XS library given by Benchmark organizers, but inverting axially the materials in the FA (Slide 9).

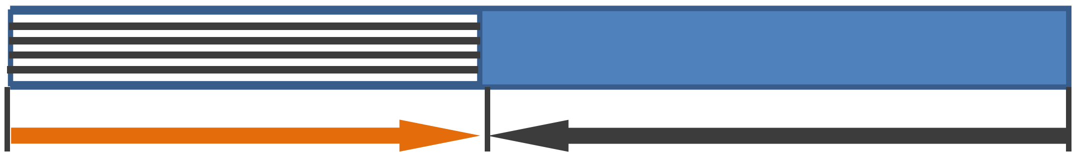
Elevation	Keff HZP
0.0 (ARO)	1.014099
71.2	0.997035
171.2	0.988555
271.2	0.969849
371.2 (ARI)	0.795158





Bottom of the core

Top of the core

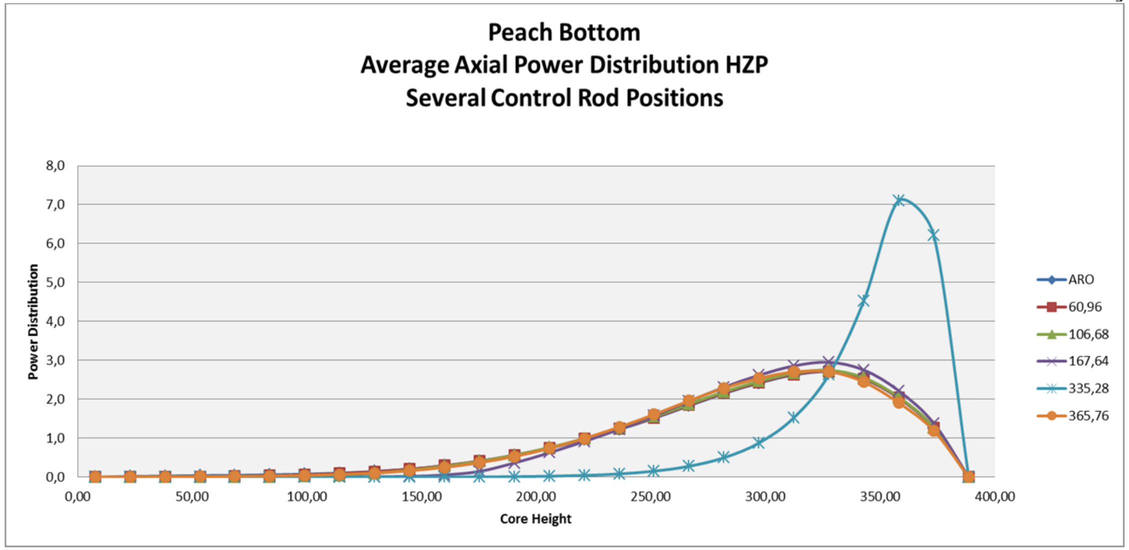


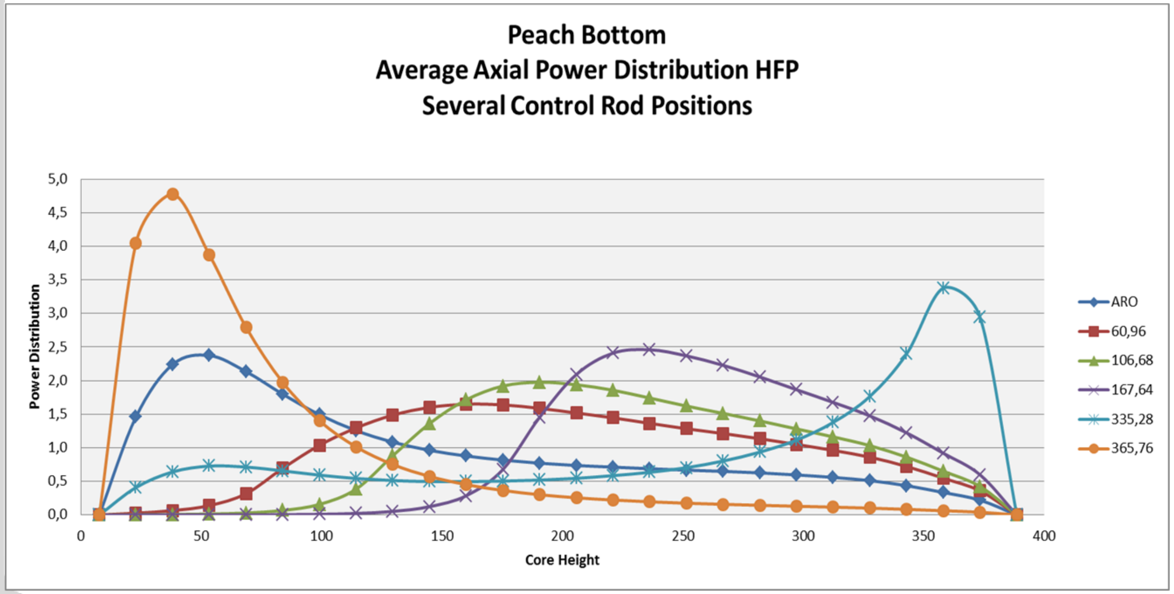
Case 3

- Peach Bottom Benchmark (Previously validated)
- DYN3D results coupled with FLOCAL
- Analysis of the axial power profile

Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.082898	1.017999
60.96	1.082893	1.021462
106.68	1.082869	1.022193
167.64	1.082507	1.020976
335.28	0.973378	0.842685
371,2 (ARI)	0.899009	0.758581

Case 3


Peach Bottom
Average Axial Power Distribution HZP
Several Control Rod Positions
Power Distribution
Core Height
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0,00
50,00
100,00
150,00
200,00
250,00
300,00
350,00
400,00
ARO
60,96
106,68
167,64
335,28
365,76


Peach Bottom
Average Axial Power Distribution HFP
Several Control Rod Positions
Power Distribution
Core Height
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0
50
100
150
200
250
300
350
400
ARO
60,96
106,68
167,64
335,28
365,76

Case 3

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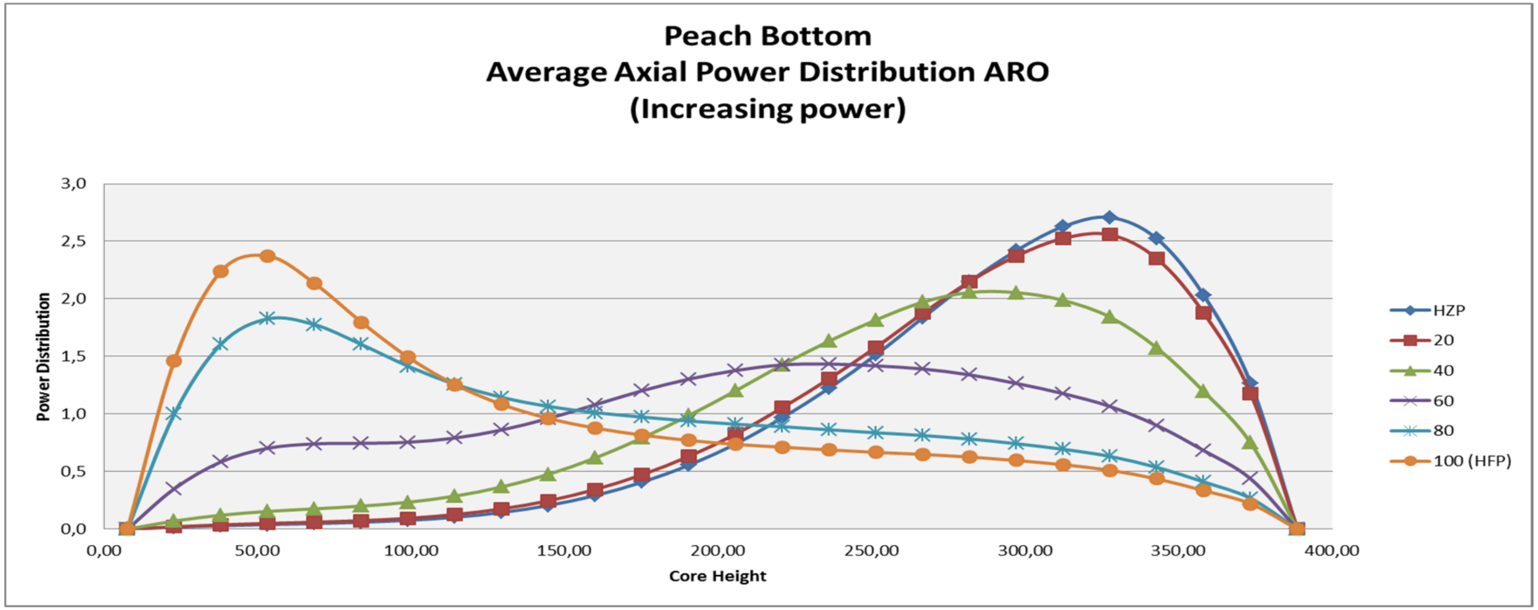


- DYN3D executed for this case successfully.
- The behaviour of axial power distribution as we expected.

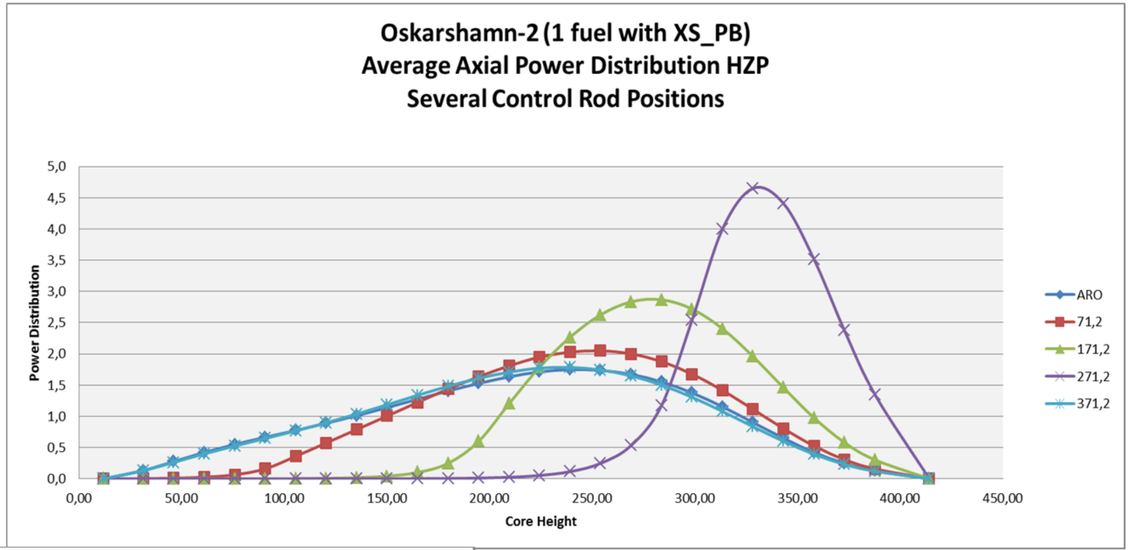
INR

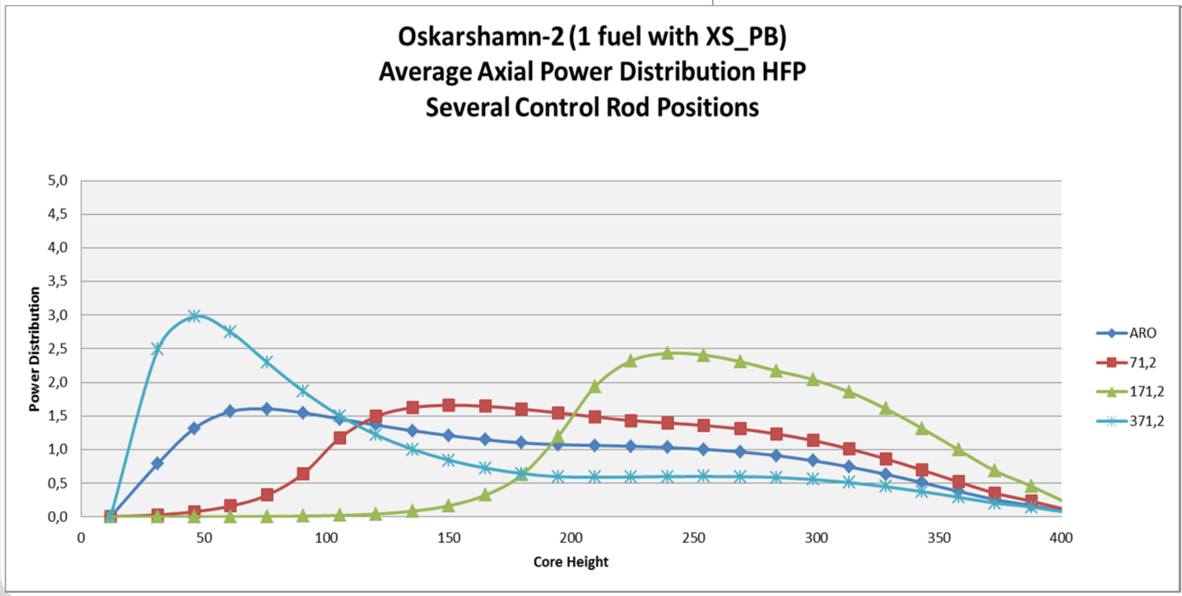
Case 4

- Input deck for Oskarshamn-2 but considering the XS library of Peach Bottom Benchmark and repeating one fuel assembly in the whole core.

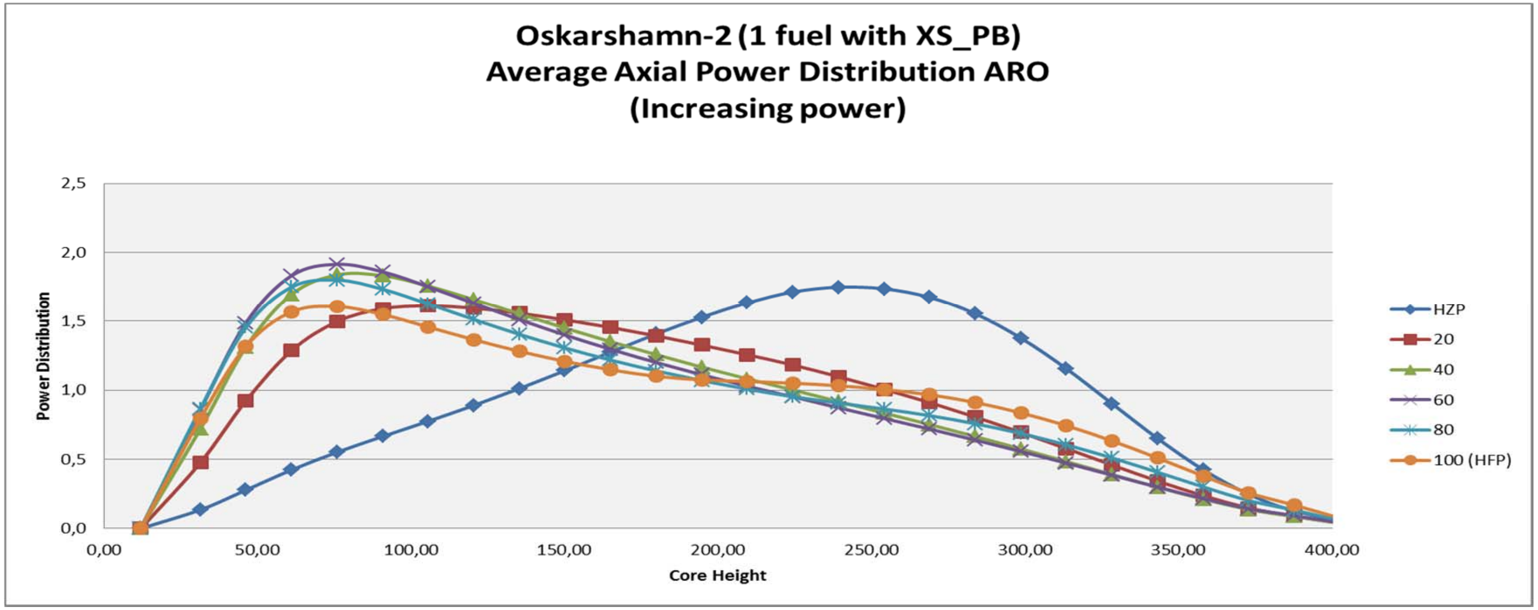
Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.172246	1.08452
71.2	1.171262	1.080034
171.2	1.163719	1.066463
271.2	1.113755	NaN
371.2 (ARI)	0.937954	0.752765

Case 4


Oskarshamn-2 (1 fuel with XS_PB)
Average Axial Power Distribution HZP
Several Control Rod Positions
Power Distribution
Core Height
ARO
71,2
171,2
271,2
371,2


Oskarshamn-2 (1 fuel with XS_PB)
Average Axial Power Distribution HFP
Several Control Rod Positions
Power Distribution
Core Height
ARO
71,2
171,2
371,2

Case 4

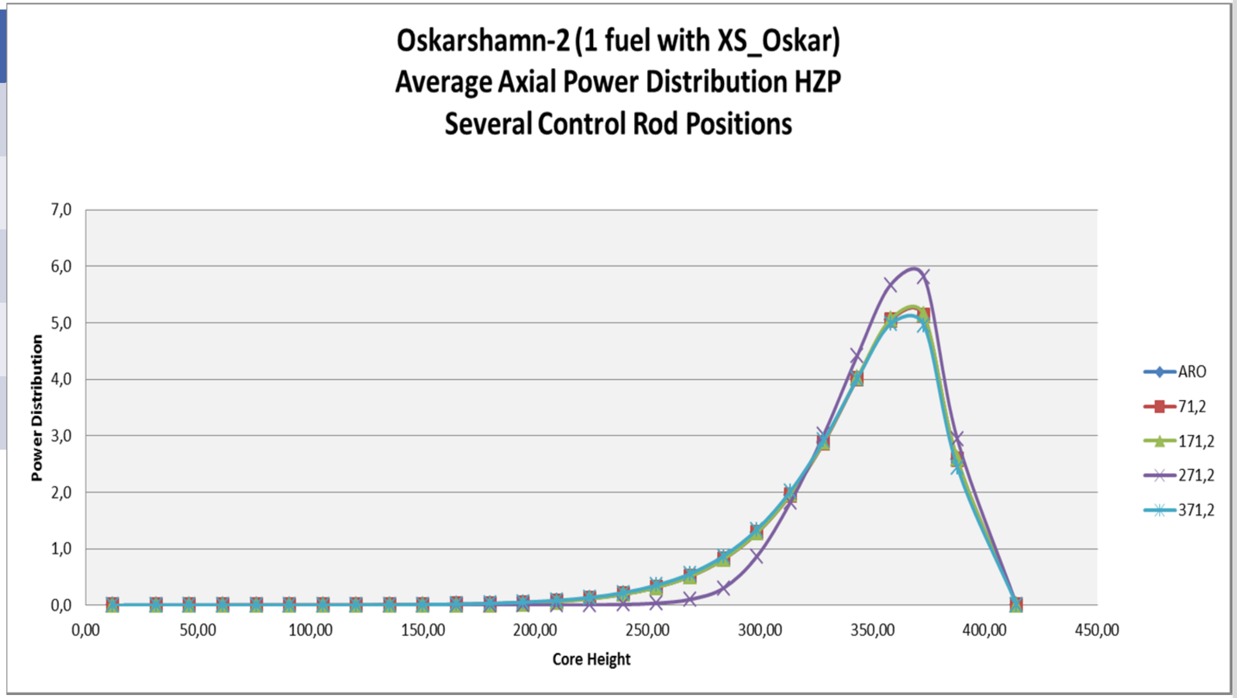


- The behaviour of axial power distribution as we expected.

Case 5

- Input deck for Oskarshamn-2 but considering the Oskarshamn XS library and one fuel assembly loaded in the all the core.

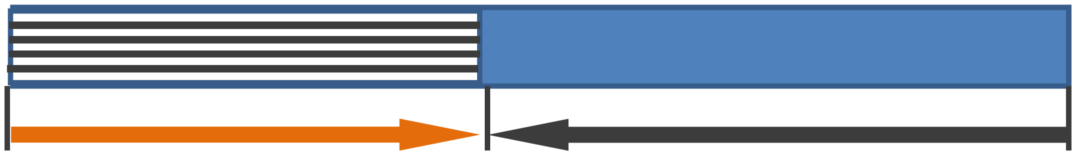
Elevation	Keff HZP
0.0 (ARO)	0.906970
71.2	0.906969
171.2	0.906968
271.2	0.905266
371.2 (ARI)	0.713506



HFP
Calc. Failed

Bottom of the core

Top of the core



Conclusions and Outlook

- Objective: test the DYN3D input deck for Oskarshamn-2 and the XS
- The HZP calculations show a big accumulation of the power distribution in the top of the core.
- Some calculations at HFP Failed.
  - The same tendency in the axial power profile
  - Too high values of the power which produce unphysical temperatures in FLOCAL and extrapolation of the XS conduce to code crash.
- The values of K_{eff} seem to be OK at first sight.

FUTURE WORK

- Further testing of the XS libraries
  - Could be an error in the geometry definition of DYN3D
  - Could be a problem in XS libraries or in the material type definition
- Once fixed those issues:
  - NURESAFE work can continue within WP1.3
  - Next will follow coupled neutronics computations to this model