

BLIND-PHASE RESULTS OF THE FFTF NEUTRONIC BENCHMARK



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FFTF NEUTRONICS BENCHMARK Specifications

- FFTF was a 400-MWt SFR design operating in the USA
- The IAEA initiated a CRP in 2018 on Fast Flux Test Facility (FFTF) Loss of Flow Without Scram (LOFWOS) Test #13
- Transients modeling requires neutronic feedback coefficients evaluation
- A neutronic benchmark was proposed as part of this CRP
- Results expected:
 - Neutron multiplication factor
 - Delayed neutron fraction and prompt neutron lifetime
 - Nominal power production for each assembly including fission and gamma heat
 - Global reactivity feedback coefficients:
 - Axial and Radial expansion
 - Control and safety rods
 - GEM worth
 - Fuel, Structure, Coolant density coefficients
 - Fuel Doppler Constant
- 11 participants contributed to this neutronic benchmark
- This presentations discusses results from the "blind" phase of this neutronic benchmark
 3 Argonne



Participants and Methods

Country	Organization	Neutronics Code	Modeling Methods and codes	Cross-sections library (Energy group of transport solver)		
China	INEST	NTC	Transport	HENDL		
China	NCEPU	MGGC	Diffusion	ENDF/B		
Germany	HZDR	Serpent-2	Monte-Carlo	ENDF/B.VII.1		
Germany	KIT	ERANOS, PARTISN	Transport	KIT-72 (11)		
India	IGCAR	FARCOB, MCNP4C	Diffusion, Monte Carlo	ABBN-93, ENDF/B-VIII.0		
Italy	Sapienza	ERANOS, PHISICS	Transport	JEFF3.1.1		
Japan	JAEA	MARBLE, MVP	Transport, Monte Carlo	JENDL-4.0		
Russia	IPPE	-	-	ABBN-93(26)		
Sweden	KTH	Serpent-2	Monte-Carlo	JEFF-3.2		
Switzerland	PSI	Serpent-2	Monte Carlo	JEFF-3.1.1		
U.S.A.	ANL	MC ² -3/DIF3D	Transport	ENDF/B.VII.0 (33)		

- 11 participating institutions
- Wide diversity of codes, methods and nuclear data libraries.



FFTF NEUTRONICS BENCHMARK Main Results

	ANL	HZDR	IGCAR	INEST	IPPE	JAEA	KIT	KTH	NCEPU	PSI	Rome	σ∕avg †
Neutron Multiplication Factor	0.99996	1.00003	0.99772	0.99900	0.99230	1.01689	0.99765	1.02200	0.99787	1.00574	0.99956	0.10%
Delayed Neutron Fraction (pcm)	313.1	312.9	334.0	650.0	324.0	315.7	364.0	341.0	375.0	320.9	300.0	7%
Prompt Neutron Lifetime	5.26E-7	5.43E-7	4.78E-7		5.65E-7		5.88E-7	6.3E-7		5.52E-7	4.82E-7	9%
Axial Expansion Coefficient (pcm/°C)	-0.322	-0.335	-0.227			-0.319		-0.300	-0.096	-0.221	-0.477	36%
Radial Expansion Coefficient (pcm/°C)	-1.000	-1.411	-1.220			-0.997		-0.930	-0.945	-1.522	-5.866	19%
Fuel Doppler Constant (pcm)	-629.0	-682.0	-507.5			-634.3	-509.0	-564.0	-524.3	-657.7	-687.7	12%
Fuel Density Coefficient (pcm/°C)	-1.362	-1.389	-1.450			-1.362		-1.360	-0.092	-1.363	-1.402	1%
Structure Density Coefficient (pcm/°C)	-0.121	0.219	0.200			0.093		0.100	-0.007	0.039	-0.098	221%
Sodium Density Coefficient (pcm/°C)	-0.346	-0.759	-0.912			-0.413	0.094	-0.940	-0.041	-0.274	-1.914	81%
Control and Safety Rods (pcm)	-11849	-10864			-9396	-10800		-11540	-8343	-11823	-12773	12%
Gas Expansion Modules (pcm)	-442	-394	-498		-516	-489	-448	420	-782	-475	-1201	8%

- Highlighted results are outliers (outside 2- σ from average)
- Relatively good agreement on k-eff, kinetics param., Doppler coeff., rod worths
- Larger discrepancy on other reactivity coefficients (axial/radial, GEMs, etc.)
- Results on structure and sodium density coefficients are widely spread-out



Neutron Multiplication Factor



- Average K-eff close to 1.00 good agreement with a critical core
- Relatively good agreement within participants outliers may be due to different methods and nuclear data libraries and modeling inconsistencies



Doppler Constant



 Relatively good agreement within participants – discrepancies may come from different methods and nuclear data libraries



GEM Worth



- Most participants have consistent results
- Clear outliers need to check typo/methods/post-processing and modeling inconsistencies
- It is important to get this coefficient right for the follow-up safety analyses

Power Distribution

- Deviation in results ~11% on fuel assemblies
- For other regions:
 - ~40% for GEMS
 - ~20% for Safety Rods
 - 15-40% for radial ref.
 - ~40% for MOTA/ICSA -
- Potential source of discrepancies:
 - Gamma heating transport
 - Diffusion vs. transport
 - etc.

0.4007 0.1655 0.1689 0.1600 0.1459 0.1426 0.1825 0.3645 <mark>0.3661</mark> 0.1956 0.1930 0.4094 0.2151 0.4137 0.2447 0.4046 0.1681 0.2039 0.4654 0.2597 0.1452 0.2380 0.0354 0.0561 0.0369 0.0803 0.0623 0.0703 0.2385 0.1630 0.2711 <mark>0.2579</mark> 0.1431 0.2611 0.0318 0.0264 0.0353 0.0360 0.0609 0.0314 0.0779 0.2307 0.1680 0.3405 <mark>0.2334</mark> 0.1390 0.2630 0.0714 0.0421 0.0514 0.0301 0.0495 0.0541 0.0561 0.0531 0.2587 0.1702 0.2755 0.3844 0.1436 0.2492 0.0459 0.0458 0.0379 0.0709 0.0317 0.1936 0.0591 0.0724 0.0494 0.2407 0.1615 0.4244 0.1661 0.2949 0.0542 0.0687 0.0478 0.0293 0.0444 0.0668 0.0256 0.0340 0.0860 0.0679 <mark>0.2289 0.2360</mark> 0.3826 0.1786 0.0459 0.1044 0.0521 0.1926 0.0656 0.0432 0.0432 0.0641 0.0927 0.0829 0.0920 0.1741 0.3742 0,1372 0,3983 0,0284 0,0772 0,0408 0,0542 0,0368 0,0332 0,0709 0,0495 0,0822 0,0685 0,4101 0,1906 0.3644 0.1206 0.2195 0.0858 0.0686 0.4290 0.0787 0.0636 0.1954 0.0726 0.0770 0.0489 0.2434 0.1444 0.4072 0.2258 0.1558 0.4133 0.0795 0.0804 0.4071 0.0584 0.0690 0.0604 0.0523 0.0584 0.4120 0.1418 0.2750 0.1973 0.1327 0.2642 0.0563 0.0673 0.0722 0.0400 0.0602 0.0675 0.0629 0.2258 0.1466 0.2867 0.2424 0.1266 0.4064 0.0477 0.0379 0.0453 0.0450 0.0448 0.0610 0.4056 0.1704 0.2889 0,3762 0,1491 0,1602 0,2087 0,2455 0,2449 0,2213 0,2216 0,1839 0,1757 0,3660 0.3633 0.1889 0.1430 0.1461 0.1489 0.1622 0.2133 0.4084 0.3885 0.2509 0.2471 0.3309 0.3671

Variation in Radial Power Profile Results (Standard Dev / Average)



FFTF NEUTRONICS BENCHMARK Conclusions

- This CRP provides valuable benchmark exercise to verify neutronics methods
- 11 participants to the FFTF neutronic benchmark
- Blind phase results show relatively good agreement
- Remaining outliers are being investigated in the open phase of the benchmark



THANK YOU FOR YOUR ATTENTION!



NEUTRONICS BENCHMARK

Power Distribution

Total Power Per Assembly - Fuel Range 4.0 3.5 3.0 Power (MW) ⁵ 1.5 1.0 0.5 0.0 2803 (1841-12) 2603 (A.104) 2603 (A.104) 2601 (A.204) 2302 (58) 2204 (2.204) 2304 (■ Argonne ■ HZDR ■ IGCAR ■ IPPE ■ JAEA ■ NCEPU ■ Rome ■ Average

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