Supplemental Online Material

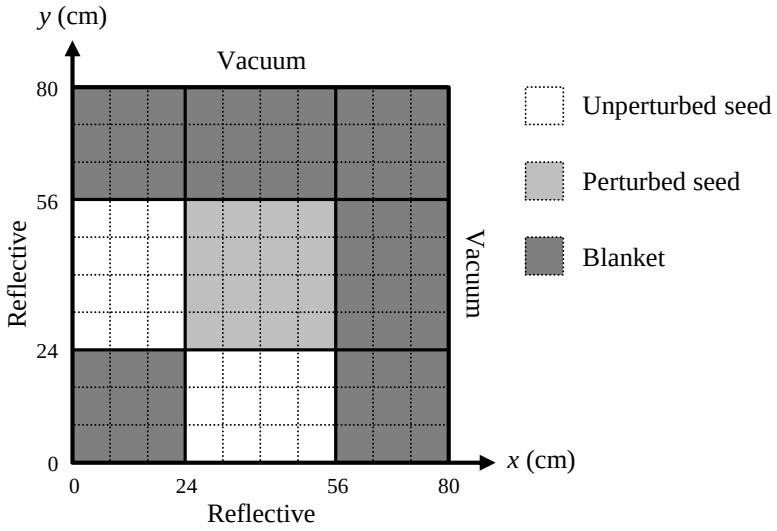


Figure S1. Top view for the TWIGL benchmark problem

Table S1. Material properties of the TWIGL benchmark problem

Material	Energy group	$\Sigma_{tr,g}$ (1/cm)	$\Sigma_{a,g}$ (1/cm)	$\nu\Sigma_{f,g}$ (1/cm)	$\Sigma_{s,g\to1}$ (1/cm)	$\Sigma_{s,g\to2}$ (1/cm)	χ_g (-)
Seed	1	0.23810	0.01000	0.00700	0.21810	0.01000	1.0
	2	0.83333	0.15000	0.20000	0.00000	0.68333	0.0
Blanket	1	0.25641	0.00800	0.00300	0.23841	0.01000	1.0
	2	0.66667	0.05000	0.06000	0.00000	0.61667	0.0
	ν	v_1(cm/sec)	v_2(cm/sec)	β (-)	λ (1/sec)		
	2.43	10^7	$2\text{x}10^5$	0.0075	0.08		

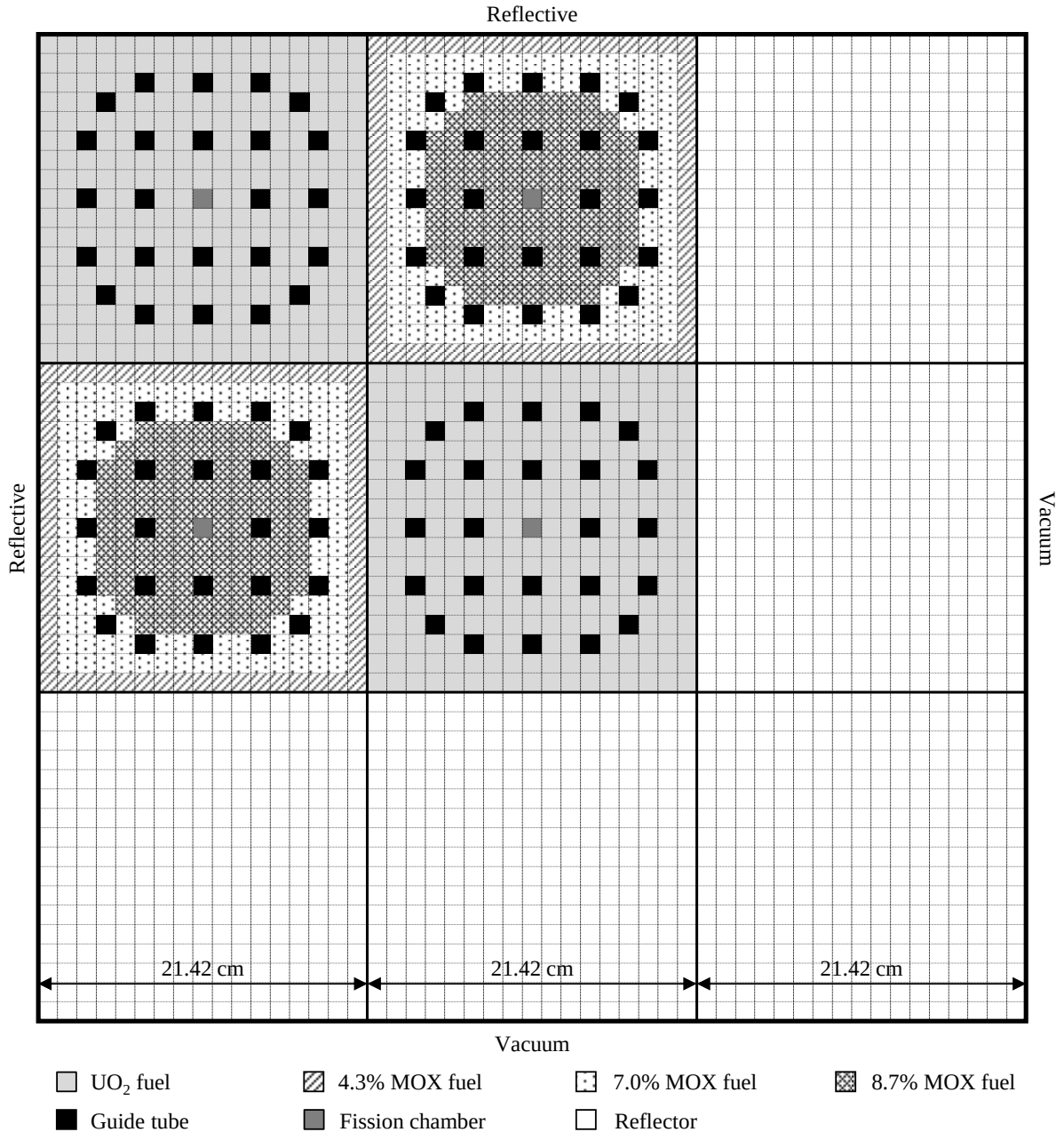


Figure S2. Top view for the C5G7-TD benchmark problem (2D model)

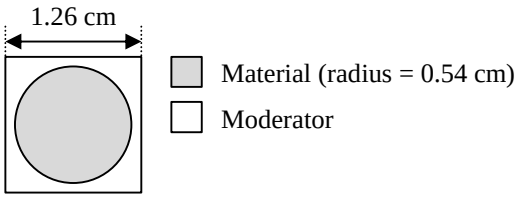


Figure S3. C5G7-TD pin cell layout

Table S2. Calculation conditions of the C5G7-TD benchmark problem

Parameters	Calculation conditions
Azimuthal division	128 for 2π with cyclic quadrature set
Polar division	3 for π/2 with TY-opt quadrature set
Ray separation	0.01 cm using cyclic ray tracing
Convergence criterion	Fission : 10^{-6}, flux : 10^{-6}
Flux region division	Reflector cell : 0.42 cm x 0.42 cm square mesh Other cells : 24 flux regions shown in Figure S4
Source approximation	Linear
Time discretization	MAF method (Fully implicit method for the shape and amplitude functions)
Time step size	Δt_{shape} = 1 sec, Δt_{amp} = 1 msec
Coarse mesh structure for the amplitude function	1.26 cm x 1.26 cm square mesh

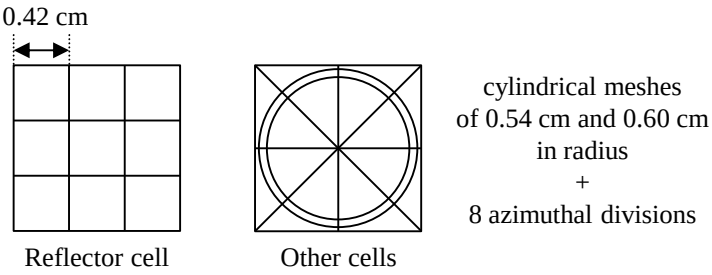


Figure S4. Flux region division

Table S3. Comparison of the initial eigenvalue for the C5G7-TD benchmark problem

	MCNP (reference)	MPACT [6]	Present study
Initial k_{eff}	$1.18646 \pm 0.07\%$	1.186673	1.186507
Relative error	-	+18 pcm	+4 pcm

Table S4. Core power transition of the C5G7-TD benchmark problem (1/3)

Time (sec)	TD 1-1	TD 1-2	TD 1-3	TD 1-4	TD 1-5	TD 2-1	TD 2-2	TD 2-3	TD 3-1	TD 3-2	TD 3-3	TD 3-4
0.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
0.1	0.93712	0.99112	0.99434	0.92450	0.91694	0.59950	0.91943	0.94784	0.87384	0.77433	0.69393	0.62767
0.2	0.87817	0.98194	0.98850	0.85545	0.84209	0.42273	0.84857	0.89993	0.76850	0.62005	0.51708	0.44159
0.3	0.82442	0.97264	0.98256	0.79388	0.77626	0.32496	0.78741	0.85690	0.68176	0.51089	0.40482	0.33275
0.4	0.77536	0.96326	0.97653	0.73879	0.71803	0.26293	0.73411	0.81805	0.60930	0.42986	0.32757	0.26174
0.5	0.73048	0.95381	0.97044	0.68931	0.66629	0.22014	0.68732	0.78281	0.54805	0.36757	0.27145	0.21206
0.6	0.68936	0.94434	0.96430	0.64472	0.62010	0.18890	0.64590	0.75071	0.49573	0.31838	0.22905	0.17560
0.7	0.65161	0.93484	0.95811	0.60440	0.57868	0.16513	0.60903	0.72135	0.45063	0.27870	0.19605	0.14786
0.8	0.61688	0.92535	0.95188	0.56781	0.54139	0.14647	0.57602	0.69439	0.41145	0.24613	0.16975	0.12617
0.9	0.58487	0.91586	0.94563	0.53451	0.50769	0.13145	0.54627	0.66955	0.37716	0.21900	0.14839	0.10883
1.0	0.55530	0.90639	0.93938	0.50412	0.47713	0.11911	0.51935	0.64658	0.34698	0.19612	0.13077	0.09471
1.1	0.57078	0.91121	0.94258	0.52030	0.49351	0.12576	0.53267	0.65750	0.36412	0.20993	0.14188	0.10392
1.2	0.58952	0.91688	0.94636	0.53990	0.51338	0.13425	0.54930	0.67121	0.38488	0.22683	0.15553	0.11525
1.3	0.61104	0.92305	0.95045	0.56257	0.53648	0.14511	0.56904	0.68735	0.40937	0.24736	0.17234	0.12934
1.4	0.63568	0.92967	0.95481	0.58877	0.56330	0.15926	0.59240	0.70623	0.43840	0.27265	0.19346	0.14723
1.5	0.66388	0.93674	0.95945	0.61909	0.59455	0.17821	0.62009	0.72823	0.47308	0.30438	0.22065	0.17064
1.6	0.69623	0.94425	0.96436	0.65431	0.63112	0.20462	0.65307	0.75391	0.51498	0.34515	0.25679	0.20244
1.7	0.73345	0.95220	0.96952	0.69544	0.67420	0.24353	0.69261	0.78394	0.56632	0.39919	0.30697	0.24796
1.8	0.77648	0.96060	0.97494	0.74384	0.72541	0.30594	0.74051	0.81923	0.63035	0.47383	0.38095	0.31822
1.9	0.82657	0.96944	0.98061	0.80131	0.78698	0.42086	0.79928	0.86098	0.71200	0.58293	0.50011	0.43997
2.0	0.88531	0.97872	0.98654	0.87035	0.86202	0.69615	0.87263	0.91082	0.81912	0.75603	0.72131	0.69842
2.1	0.89100	0.97971	0.98715	0.87688	0.86905	0.71974	0.87927	0.91535	0.82877	0.77069	0.73976	0.72008
2.2	0.89444	0.98034	0.98754	0.88077	0.87319	0.72892	0.88311	0.91804	0.83420	0.77806	0.74819	0.72919
2.3	0.89743	0.98089	0.98789	0.88415	0.87679	0.73685	0.88645	0.92037	0.83890	0.78444	0.75547	0.73707
2.4	0.90005	0.98137	0.98819	0.88712	0.87995	0.74379	0.88937	0.92242	0.84304	0.79003	0.76185	0.74395
2.5	0.90237	0.98180	0.98846	0.88975	0.88275	0.74990	0.89197	0.92424	0.84670	0.79498	0.76748	0.75003
2.6	0.90446	0.98218	0.98870	0.89211	0.88526	0.75535	0.89429	0.92587	0.84997	0.79940	0.77251	0.75545
2.7	0.90634	0.98253	0.98892	0.89423	0.88752	0.76025	0.89638	0.92733	0.85294	0.80338	0.77704	0.76033
2.8	0.90805	0.98284	0.98911	0.89616	0.88958	0.76469	0.89828	0.92866	0.85566	0.80699	0.78114	0.76476
2.9	0.90961	0.98313	0.98929	0.89793	0.89146	0.76874	0.90001	0.92988	0.85811	0.81028	0.78489	0.76879
3.0	0.91104	0.98339	0.98946	0.89955	0.89318	0.77246	0.90161	0.93099	0.86036	0.81332	0.78833	0.77250
3.1	0.91238	0.98364	0.98961	0.90106	0.89478	0.77588	0.90309	0.93204	0.86248	0.81610	0.79151	0.77593
3.2	0.91361	0.98386	0.98975	0.90245	0.89626	0.77906	0.90446	0.93300	0.86442	0.81870	0.79446	0.77910
3.3	0.91476	0.98407	0.98989	0.90375	0.89765	0.78202	0.90574	0.93389	0.86622	0.82112	0.79721	0.78206

Table S4. Core power transition of the C5G7-TD benchmark problem (2/3)

Time (sec)	TD 1-1	TD 1-2	TD 1-3	TD 1-4	TD 1-5	TD 2-1	TD 2-2	TD 2-3	TD 3-1	TD 3-2	TD 3-3	TD 3-4
3.4	0.91584	0.98427	0.99001	0.90497	0.89894	0.78479	0.90693	0.93473	0.86792	0.82338	0.79977	0.78483
3.5	0.91685	0.98446	0.99013	0.90612	0.90016	0.78739	0.90806	0.93552	0.86951	0.82551	0.80219	0.78743
3.6	0.91781	0.98463	0.99024	0.90719	0.90131	0.78985	0.90912	0.93626	0.87101	0.82752	0.80446	0.78988
3.7	0.91871	0.98480	0.99034	0.90822	0.90239	0.79217	0.91012	0.93697	0.87243	0.82942	0.80662	0.79220
3.8	0.91957	0.98496	0.99044	0.90918	0.90342	0.79437	0.91107	0.93763	0.87377	0.83122	0.80866	0.79440
3.9	0.92038	0.98510	0.99053	0.91011	0.90440	0.79646	0.91197	0.93827	0.87506	0.83293	0.81060	0.79649
4.0	0.92115	0.98525	0.99062	0.91098	0.90534	0.79846	0.91284	0.93887	0.87628	0.83457	0.81246	0.79849
4.1	0.92191	0.98539	0.99071	0.91183	0.90624	0.80037	0.91367	0.93945	0.87746	0.83615	0.81425	0.80038
4.2	0.92262	0.98552	0.99079	0.91264	0.90709	0.80219	0.91446	0.94000	0.87858	0.83765	0.81595	0.80220
4.3	0.92331	0.98564	0.99087	0.91341	0.90792	0.80394	0.91522	0.94053	0.87965	0.83908	0.81758	0.80395
4.4	0.92396	0.98576	0.99094	0.91415	0.90871	0.80563	0.91595	0.94104	0.88068	0.84046	0.81914	0.80563
4.5	0.92460	0.98588	0.99101	0.91487	0.90947	0.80725	0.91665	0.94154	0.88168	0.84179	0.82065	0.80725
4.6	0.92521	0.98599	0.99108	0.91555	0.91020	0.80881	0.91732	0.94201	0.88264	0.84307	0.82210	0.80881
4.7	0.92580	0.98610	0.99115	0.91622	0.91091	0.81031	0.91798	0.94247	0.88356	0.84431	0.82351	0.81031
4.8	0.92637	0.98620	0.99122	0.91686	0.91159	0.81177	0.91861	0.94291	0.88446	0.84550	0.82486	0.81177
4.9	0.92692	0.98630	0.99128	0.91749	0.91225	0.81318	0.91922	0.94334	0.88532	0.84666	0.82618	0.81318
5.0	0.92745	0.98640	0.99134	0.91809	0.91289	0.81455	0.91981	0.94375	0.88616	0.84778	0.82744	0.81455
5.1	0.92797	0.98649	0.99140	0.91868	0.91353	0.81589	0.92039	0.94416	0.88698	0.84889	0.82869	0.81589
5.2	0.92848	0.98659	0.99146	0.91925	0.91413	0.81718	0.92095	0.94455	0.88778	0.84994	0.82989	0.81718
5.3	0.92897	0.98667	0.99151	0.91980	0.91472	0.81844	0.92149	0.94493	0.88854	0.85097	0.83106	0.81844
5.4	0.92944	0.98676	0.99157	0.92034	0.91529	0.81965	0.92201	0.94530	0.88929	0.85197	0.83219	0.81966
5.5	0.92991	0.98685	0.99162	0.92086	0.91585	0.82084	0.92253	0.94566	0.89002	0.85295	0.83330	0.82084
5.6	0.93036	0.98693	0.99167	0.92137	0.91639	0.82200	0.92303	0.94601	0.89073	0.85390	0.83437	0.82200
5.7	0.93080	0.98701	0.99172	0.92187	0.91692	0.82312	0.92352	0.94635	0.89142	0.85482	0.83542	0.82312
5.8	0.93123	0.98709	0.99177	0.92236	0.91744	0.82422	0.92399	0.94668	0.89210	0.85572	0.83644	0.82422
5.9	0.93165	0.98716	0.99182	0.92283	0.91794	0.82529	0.92445	0.94701	0.89275	0.85660	0.83744	0.82530
6.0	0.93205	0.98723	0.99186	0.92329	0.91843	0.82634	0.92491	0.94732	0.89340	0.85746	0.83842	0.82634
6.1	0.93246	0.98731	0.99191	0.92375	0.91892	0.82737	0.92535	0.94763	0.89403	0.85831	0.83937	0.82738
6.2	0.93285	0.98738	0.99195	0.92419	0.91939	0.82837	0.92579	0.94794	0.89465	0.85914	0.84031	0.82838
6.3	0.93323	0.98745	0.99199	0.92462	0.91985	0.82935	0.92621	0.94823	0.89525	0.85994	0.84122	0.82936
6.4	0.93360	0.98752	0.99204	0.92504	0.92029	0.83030	0.92662	0.94852	0.89583	0.86072	0.84210	0.83030
6.5	0.93397	0.98758	0.99208	0.92546	0.92073	0.83125	0.92703	0.94881	0.89641	0.86150	0.84298	0.83125
6.6	0.93433	0.98765	0.99212	0.92586	0.92116	0.83216	0.92742	0.94908	0.89697	0.86224	0.84383	0.83216
6.7	0.93468	0.98771	0.99216	0.92626	0.92159	0.83306	0.92781	0.94936	0.89753	0.86299	0.84467	0.83307

Table S4. Core power transition of the C5G7-TD benchmark problem (3/3)

Time (sec)	TD 1-1	TD 1-2	TD 1-3	TD 1-4	TD 1-5	TD 2-1	TD 2-2	TD 2-3	TD 3-1	TD 3-2	TD 3-3	TD 3-4
6.8	0.93502	0.98777	0.99220	0.92664	0.92200	0.83394	0.92819	0.94962	0.89806	0.86370	0.84548	0.83394
6.9	0.93536	0.98784	0.99223	0.92702	0.92240	0.83480	0.92856	0.94988	0.89859	0.86441	0.84629	0.83480
7.0	0.93569	0.98789	0.99227	0.92740	0.92280	0.83564	0.92893	0.95014	0.89911	0.86511	0.84708	0.83565
7.1	0.93602	0.98796	0.99231	0.92777	0.92319	0.83648	0.92929	0.95039	0.89963	0.86579	0.84785	0.83649
7.2	0.93633	0.98801	0.99234	0.92813	0.92357	0.83730	0.92964	0.95064	0.90013	0.86646	0.84861	0.83730
7.3	0.93665	0.98807	0.99238	0.92848	0.92395	0.83810	0.92999	0.95088	0.90062	0.86712	0.84936	0.83811
7.4	0.93695	0.98812	0.99241	0.92883	0.92432	0.83889	0.93033	0.95112	0.90110	0.86776	0.85009	0.83889
7.5	0.93725	0.98818	0.99245	0.92917	0.92468	0.83966	0.93066	0.95135	0.90157	0.86840	0.85081	0.83966
7.6	0.93755	0.98823	0.99248	0.92950	0.92504	0.84042	0.93099	0.95158	0.90204	0.86902	0.85151	0.84042
7.7	0.93784	0.98828	0.99251	0.92983	0.92538	0.84116	0.93131	0.95180	0.90250	0.86963	0.85220	0.84117
7.8	0.93812	0.98834	0.99254	0.93015	0.92573	0.84189	0.93162	0.95202	0.90294	0.87023	0.85288	0.84190
7.9	0.93840	0.98839	0.99258	0.93047	0.92606	0.84261	0.93193	0.95224	0.90338	0.87082	0.85355	0.84262
8.0	0.93868	0.98844	0.99261	0.93078	0.92639	0.84332	0.93224	0.95245	0.90382	0.87140	0.85421	0.84332
8.1	0.93895	0.98849	0.99264	0.93109	0.92672	0.84401	0.93254	0.95266	0.90425	0.87197	0.85486	0.84402
8.2	0.93922	0.98853	0.99267	0.93139	0.92704	0.84470	0.93284	0.95287	0.90467	0.87254	0.85550	0.84470
8.3	0.93948	0.98858	0.99270	0.93169	0.92736	0.84537	0.93313	0.95307	0.90508	0.87309	0.85612	0.84537
8.4	0.93974	0.98863	0.99272	0.93198	0.92767	0.84603	0.93341	0.95327	0.90548	0.87363	0.85674	0.84603
8.5	0.93999	0.98867	0.99275	0.93226	0.92797	0.84668	0.93369	0.95347	0.90588	0.87416	0.85734	0.84668
8.6	0.94024	0.98872	0.99278	0.93254	0.92827	0.84732	0.93397	0.95366	0.90627	0.87469	0.85793	0.84732
8.7	0.94049	0.98876	0.99281	0.93282	0.92857	0.84795	0.93424	0.95385	0.90666	0.87520	0.85852	0.84795
8.8	0.94073	0.98880	0.99283	0.93309	0.92886	0.84857	0.93451	0.95404	0.90704	0.87571	0.85910	0.84857
8.9	0.94097	0.98885	0.99286	0.93336	0.92914	0.84918	0.93477	0.95422	0.90741	0.87621	0.85966	0.84918
9.0	0.94120	0.98889	0.99289	0.93363	0.92942	0.84978	0.93503	0.95441	0.90778	0.87671	0.86022	0.84978
9.1	0.94143	0.98893	0.99291	0.93389	0.92970	0.85037	0.93529	0.95458	0.90815	0.87719	0.86078	0.85038
9.2	0.94166	0.98897	0.99294	0.93415	0.92998	0.85095	0.93554	0.95476	0.90851	0.87767	0.86132	0.85096
9.3	0.94188	0.98901	0.99296	0.93440	0.93025	0.85153	0.93578	0.95493	0.90886	0.87814	0.86185	0.85153
9.4	0.94210	0.98905	0.99299	0.93465	0.93051	0.85209	0.93603	0.95510	0.90920	0.87861	0.86238	0.85210
9.5	0.94232	0.98909	0.99301	0.93489	0.93077	0.85265	0.93627	0.95527	0.90955	0.87906	0.86290	0.85265
9.6	0.94253	0.98913	0.99303	0.93514	0.93103	0.85320	0.93650	0.95544	0.90988	0.87951	0.86341	0.85320
9.7	0.94274	0.98917	0.99306	0.93537	0.93128	0.85374	0.93674	0.95560	0.91021	0.87996	0.86391	0.85374
9.8	0.94295	0.98920	0.99308	0.93561	0.93153	0.85427	0.93697	0.95576	0.91054	0.88040	0.86441	0.85428
9.9	0.94316	0.98924	0.99310	0.93584	0.93178	0.85480	0.93719	0.95592	0.91086	0.88083	0.86490	0.85480
10.0	0.94336	0.98928	0.99312	0.93607	0.93202	0.85532	0.93742	0.95607	0.91118	0.88125	0.86539	0.85533

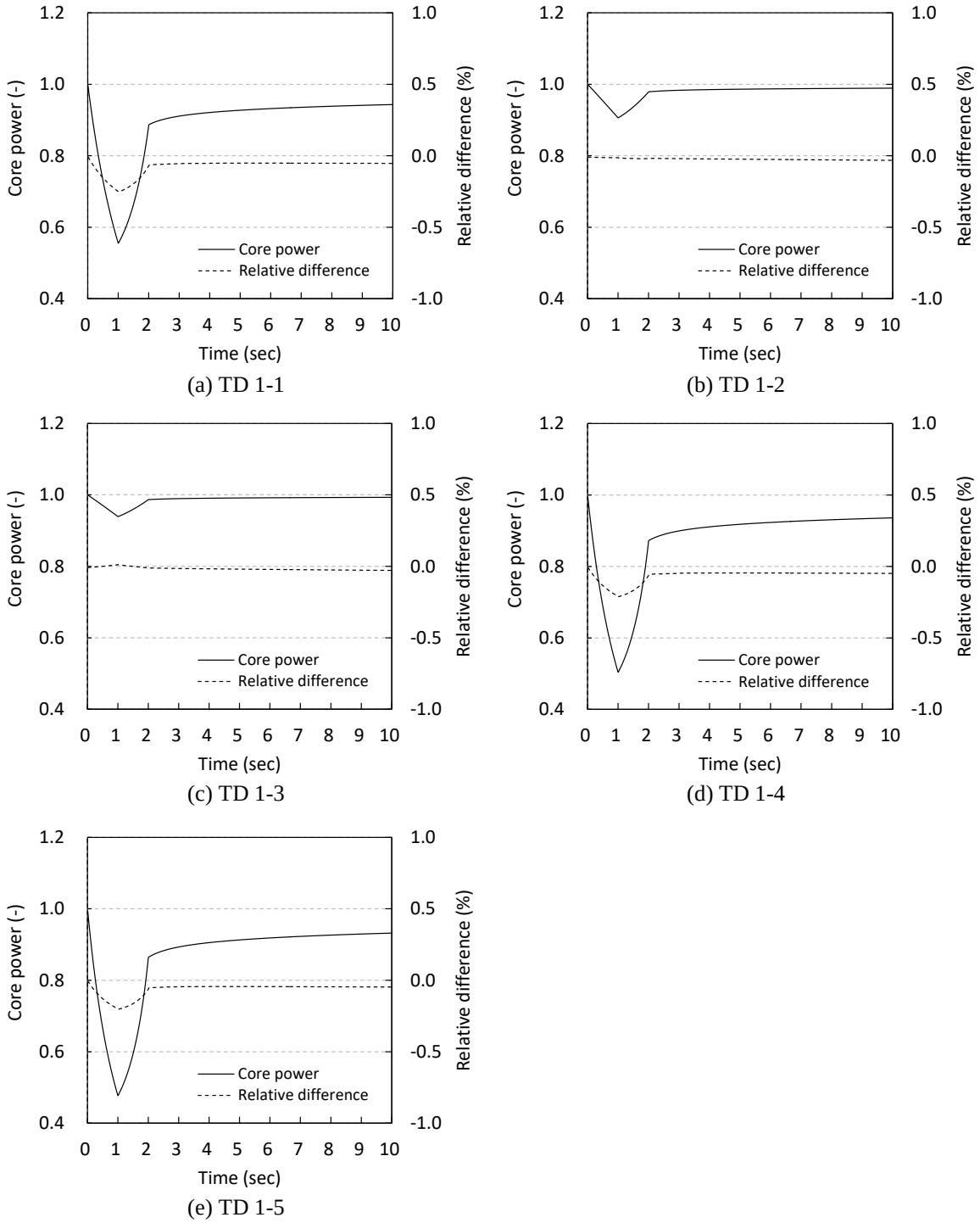
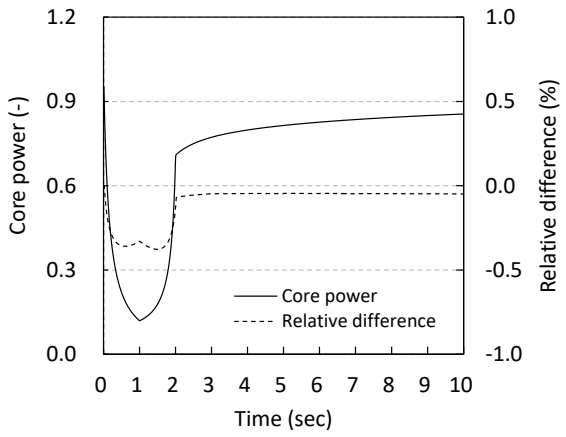
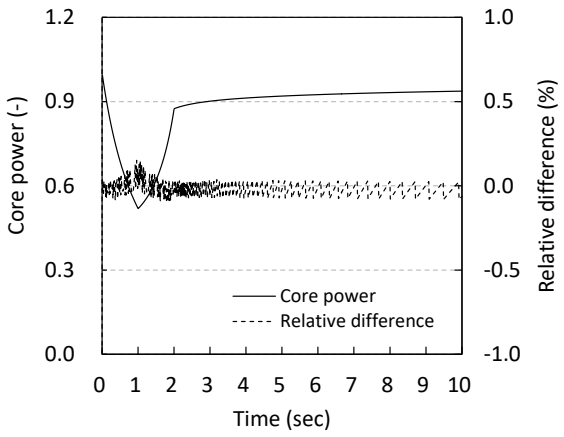


Figure S2. Comparison of the core power transition with MPACT (1/3)

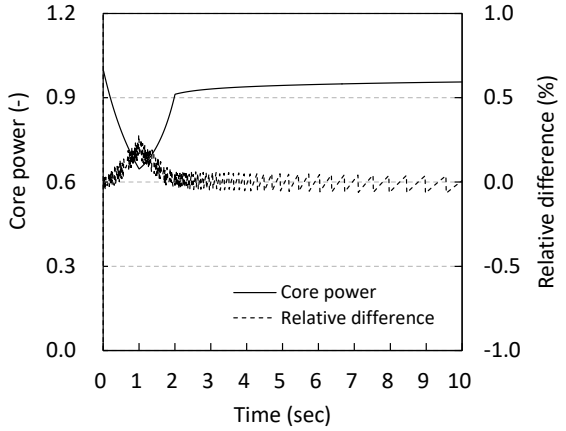
$$\text{Relative difference (\%)} = \frac{P_{present\ study} - P_{MPACT}}{P_{MPACT}} \times 100 \quad (P: \text{core power}).$$



(f) TD 2-1

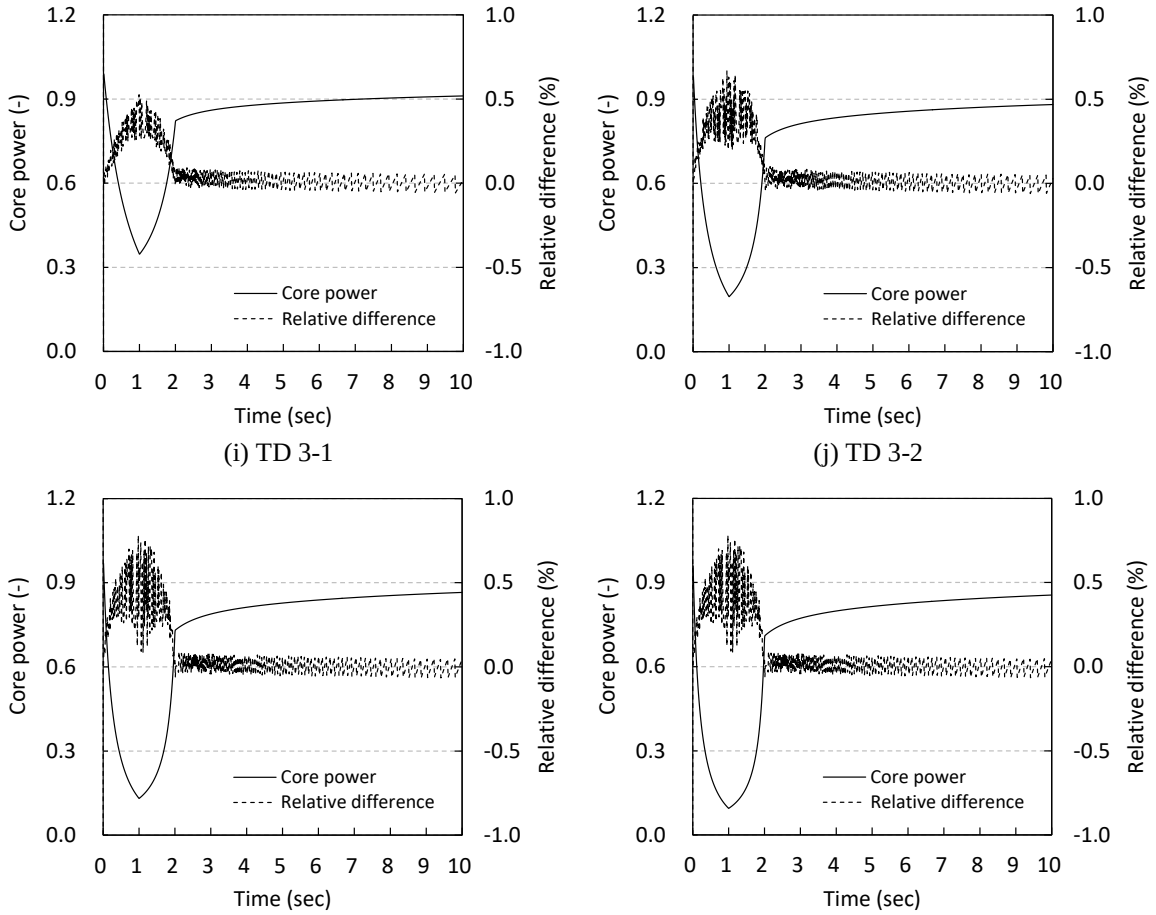


(g) TD 2-2



(h) TD 2-3

Figure S2. Comparison of the core power transition with MPACT (2/3)



(i) TD 3-1 (j) TD 3-2

(k) TD 3-3 (l) TD 3-4

Figure S2. Comparison of the core power transition with MPACT (3/3)

Since the reference calculation results of MPACT are provided in only 3 effective digits for TD 2-2 ~ TD 3-4 [6], the relative difference between the present study and the MPACT for them includes larger rounding error than TD 1-1 ~ TD 2-1.