

3. CORE CHARACTERISTICS

3.1.	Reference number of core for which chapter 3 data apply
3.2.	Fissile material content of a core (kg)
3.2.1.	U 235
3.2.2.	Pu 239
3.2.3.	Total plutonium (all isotopes)

Experimental Fast Reactors

Plant	3.1	3.2.1.	3.2.2.	3.2.3.
Rapsodie (France)		79.5	31.5	
KNK-II (Germany)		312	28	39
FBTR (India)	MK II	0.7	85.6	124.4
PEC (Italy)		79	175	310
JOYO (Japan)	MK II	94*	140	220*
DFR (UK)		247	3	3.5
BOR-60 (Russia)		95	53**	58
EBR-II (USA)	Run 128	229	4.5	5.0
Fermi (USA)		484	0	0
FFTF (USA)		14	516	587
BR-10 (Russia)		113		
CEFR (China)		97.6	93.2	121.6

Demonstration or Prototype Fast Reactors

Phénix (France)		35	717	931
SNR-300 (Germany)		57	1058	1536
PFBR (India)		14	1271	1850
MONJU (Japan)		13.5	870	1400
PFR (UK)	Equilibrium	50	760	950
CRBRP (USA)		7.6	1468	1705
BN-350 (Kazakhstan)	Equilibrium	1220***	75	77
BN-600 (Russia)	Equilibrium	2020***	110	112
ALMR (USA)		14		2283

Commercial Size Reactors

Super-Phénix 1 (France) 1st core		142	4054	5780
Super-Phénix 2 (France)				
SNR 2 (Germany)		210	4800	8000
DFBR (Japan)		40	2430	4130
CDFR (UK)	Reference	60	3000	3400
BN-1600 (Russia)	Equilibrium	80	5400**	7900
BN-800 (Russia)	Equilibrium	30	1870**	2710
EFR		81		8808
ALMR (USA)		30		2800

* MK II; (175, 160, respectively, in MK-I)

** Pu-239 and Pu-241

*** for cores with UO₂ fuel

CORE CHARACTERISTICS

<u>3.3.</u>	Core volume fractions averaged over whole core, excluding experiments
3.3.1.	Fuel
3.3.2.	Coolant
3.3.3.	Steel
3.3.4.	Void or fission gas space

Experimental Fast Reactors

Plant	3.3.1.	3.3.2.	3.3.3.	3.3.4.
Rapsodie (France)	0.425	0.396	0.136	0.023
KNK-II (Germany)	0.32	0.43	0.21	0.04**
FBTR (India)	0.374	0.354	0.238	0.034
PEC (Italy)	0.346	0.376	0.248	0.030
JOYO (Japan)	0.37*	0.37*	0.23*	0.03
DFR (UK)	0.40	0.40	0.20	0
BOR-60 (Russia)	0.48	0.29	0.23	0
EBR-II (USA)	0.318	0.487	0.195	0
Fermi (USA)	0.279	0.472	0.249	0
FFTF (USA)	0.31	0.39	0.26	0.04
BR-10 (Russia)	0.445	0.287	0.218	0.05
CEFR (China)	0.381	0.397	0.207	0.015

Demonstration or Prototype Fast Reactors

Phénix (France)	0.37	0.35	0.25	0.03
SNR-300 (Germany)	0.295	0.50	0.19	0.015
PFBR (India)	0.333	0.410	0.239	0.018
MONJU (Japan)	0.335	0.400	0.245	0.020
PFR (UK)	0.35	0.41	0.21	0.03
CRBRP (USA)	0.325	0.419	0.234	0.022
BN-350 (Kazakhstan)	0.380	0.33	0.22	0.07
BN-600 (Russia)	0.375	0.34	0.215	0.07
ALMR (USA)	0.378	0.366	0.257	0

Commercial Size Reactors

Super-Phénix 1 (France)	0.37	0.34	0.24	0.05
Super-Phénix 2 (France)	0.37	0.37	0.24	0.02
SNR 2 (Germany)	0.364	0.39	0.22	0.026
DFBR (Japan)	0.39	0.33	0.23	0.05
CDFR (UK)	0.25	0.51	0.18	0.06
BN-1600 (Russia)	0.415	0.306	0.229	0.05
BN-800 (Russia)	0.340	0.390	0.220	0.05
EFR	0.361	0.329	0.235	0.075
ALMR (USA)	0.378	0.366	0.257	0

* MK II; (0.36, 0.40, 0.21, respectively, in MK-I)

** volume fraction of moderating material

CORE CHARACTERISTICS

- 3.4. Power density (kW/litre of fuel) [fuel volume defined by space within cladding]
 3.4.1. Maximum
 3.4.2. Average over core
 3.5. Mean length of reactor run (days)
 3.6. Mean length of routine shutdown for refuelling (days), excluding long maintenance periods

Plant	Experimental Fast Reactors			
	3.4.1.	3.4.2.	3.5.	3.6.
Rapsodie (France)	3060	2210	80	10
KNK-II (Germany)*	1280/886	985/599		
FBTR (India)	2344	1806	45-60	7
PEC (Italy)	1384	930	60	15
JOYO (Japan)	2195**	1225**	45	15
DFR (UK)	1250	900	55	
BOR-60 (Russia)	1940	1615	80	30
EBR-II (USA)	2704	1610	49	7
Fermi (USA)	2774	1642	14	
FFTF (USA)	1857	1114	107	***
BR-10 (Russia)	2182	1588	100	12
CEFR (China)	1867	1132	73	14

Demonstration or Prototype Fast Reactors				
Phénix (France)	1950	1200	90	7
SNR-300 (Germany)	1613	1016	588****	
PFBR (India)	1763	1207	140	22
MONJU (Japan)			148	30
PFR (UK)	1720	1160	90	21
CRBRP (USA)	1983	1023	275	90
BN-350 (Kazakhstan)	1995	1155	105	10
BN-600 (Russia)	1587	940	160	15
ALMR (USA)	1070	708	310	55

Commercial Size Reactors				
Super-Phénix 1 (France)	1250	785	640	120*****
Super-Phénix 2 (France)	1200	755	270	15 or 45
SNR 2 (Germany)	800	500	365	30
DFBR (Japan)			456	60
CDFR (UK)	2400	1750	270	28
BN-1600 (Russia)	1130	670	330	35
BN-800 (Russia)	1796	1152	140	15
EFR	1100	670	425	20
ALMR (USA)	950	610	595	105

- * test subassembly/driver subassembly
 ** MK II;
 *** 1 at 46 days and 2 at 25 days
 **** 588 days or 441 equivalent full power days
 ***** whole core refuelling

CORE CHARACTERISTICS

- 3.6. Mean residence time for subassemblies (full power days)
- 3.6.1. Internal blanket (if applicable)
- 3.6.2. Inner core
- 3.6.3. Outer core
- 3.6.4. Row 1 radial blanket
- 3.6.5. Row 2 radial blanket
- 3.6.6. Row 3 radial blanket

Experimental Fast Reactors

Plant	3.6.1.	3.6.2.	3.6.3.	3.6.4.	3.6.5.	3.6.6.
Rapsodie (France)		400		720	1350	1690
KNK-II (Germany)		455	455	1700		
FBTR (India)		225				
PEC (Italy)		330				
JOYO (Japan)			270*	**	**	**
DFR (UK)		110	110			
BOR-60 (Russia)		730	900	1450	1800	2200
EBR-II (USA)		395	480			
Fermi (USA)		75				
FFTF (USA)		720	600			
BR-10 (Russia)		880				
CEFR (China)		162****				

Demonstration or Prototype Fast Reactors

Phénix (France)	600	800	600	900	1400
SNR-300 (Germany)	441	441	613	1728	
PFBR (India)	489	551	400	750	1825
MONJU (Japan)	740	740	740	740	740
PFR (UK)	300	400	800	1200	1200
CRBRP (USA)	328	328	328	878	1153
BN-350 (Kazakhstan)	525	525-735	630	1050	1470
BN-600 (Russia)	480	480	640	960	1280
ALMR (USA)	1241	1241			

Commercial Size Reactors

Super-Phénix 1 (France)	640	640	320*****	640*****	640*****
Super-Phénix 2 (France)	1350	1350	1620		
SNR 2 (Germany)	1100	1100	2200		
DFBR (Japan)	1370	1370	1370	1370	
CDFR (UK)	550	550	1000	1500	1500
BN-1600 (Russia)	1320	1320	1320		
BN-800 (Russia)	420	420	420		
EFR	1700	1700	2720		
ALMR (USA)	1189	1784		2379***	

* MK-II; (250 in MK-I)

** MK II; (300 for row 1-4 in MK-I)

*** Cumulative, including residence time in internal blanket before shuffling to radial blanket

**** 224 and 336 later

***** Anticipated radial blanket unloading.

CORE CHARACTERISTICS

3.7.	Burn-up (MWd/t of heavy metal)
3.7.1.	Maximum achieved
3.7.2.	Average achieved
3.7.3.	Maximum target
3.7.4.	Average target

Experimental Fast Reactors

Plant	3.7.1.	3.7.2.	3.7.3.	3.7.4.
Rapsodie (France)	102000			
KNK-II (Germany)	172000	75000	69000	52000
FBTR (India)			50000	38000
PEC (Italy)			65000	57000
JOYO (Japan)	84000*	42000	90000*	60000
DFR (UK)	3000	2500		
BOR-60 (Russia)	260000			
EBR-II (USA)	80000	66000		
Fermi (USA)	4000	3000	10000	8000
FFTF (USA)	155000	70000		
BR-10 (Russia)	62300	45500		
CEFR (China)			50000	38000

Demonstration or Prototype Fast Reactors

Phénix (France)	132000	91000	170000	125000
SNR-300 (Germany)			86000	57000
PFBR (India)			100000	68000
MONJU (Japan)			940000	80000
PFR (UK)	200000	150000	250000	
CRBRP (USA)			74200	50000
BN-350 (Kazakhstan)	97000	58000	120000	70000
BN-600 (Russia)	97000	60000	120000	72000
ALMR (USA)			125000	90000

Commercial Size Reactors

Super-Phénix 1 (France)	80000	50000	113000	70000
Super-Phénix 2 (France)			136000	85000
SNR 2 (Germany)			150000	120000
DFBR (Japan)			110000	90000
CDFR (UK)			170000	115000
BN-1600 (Russia)			170000	115000
BN-800 (Russia)			98000	66000
EFR			190000	134000**
ALMR (USA)			150000	100000

* MK II; (40000, 42000, respectively, in MK-I)

** Average core discharge burn-up

CORE CHARACTERISTICS

- 3.8. Neutron flux ($\times 10^{15} \text{n/cm}^2 \text{ s}$)
 3.8.1. Maximum
 3.8.2. Average

Experimental Fast Reactors

Plant	3.8.1.	3.8.2.
Rapsodie (France)	3.2	2.3
KNK-II (Germany)	1.9	1.3
FBTR (India)	3.4	2.5
PEC (Italy)	4.0	2.6
JOYO (Japan)	5.1*	2.6*
DFR (UK)	2.5	1.9
BOR-60 (Russia)	3.5	2.5
EBR-II (USA)	2.7	1.6
Fermi (USA)	4.5	2.6
FFTF (USA)	7.0	4.2
BR-10 (Russia)	0.86	0.63
CEFR (China)	2.97	1.76

Demonstration or Prototype Fast Reactors

Phénix (France)	6.8	
SNR-300 (Germany)	6.7	4.9
PFBR (India)	8.1	4.5
MONJU (Japan)	6.0	3.6
PFR (UK)	7.6	5.0
CRBRP (USA)	5.5	3.6
BN-350 (Kazakhstan)	5.4	3.5
BN-600 (Russia)	6.5	4.3
ALMR (USA)	4.5	2.9

Commercial Size Reactors

Super-Phénix 1 (France)	6.1	3.6
Super-Phénix 2 (France)	5.0	
SNR 2 (Germany)	5.4	
DFBR (Japan)		
CDFR (UK)	10	5.9
BN-1600 (Russia)	5.5	
BN-800 (Russia)	8.8	5.6
EFR	5.3	3.5
ALMR (USA)	3.3	2.3

* MK II; (3.2, 1.9, respectively, in MK-I, 75 MWth)

CORE CHARACTERISTICS

3.9. Percentage of subassemblies changed at each shutdown
(refuelling plan at equilibrium condition)

3.9.1. Inner core fuel

3.9.2. Outer core fuel

3.9.3. Control rods

3.9.4. Radial blanket, innermost row

Experimental Fast Reactors

Plant	3.9.1.	3.9.2.	3.9.3.	3.9.4.
Rapsodie (France)	20		20	
KNK-II (Germany)	100	100	100	
FBTR (India)	selective removal of subassemblies			
PEC (Italy)	20		16.7	
JOYO (Japan)		16.7*	16.7	
DFR (UK)	50	50	33	0
BOR-60 (Russia)	12-16			5-7
EBR-II (USA)	Remove fuel at 8% burn-up			
Fermi (USA)	Change 1-2 subassemblies every 14 days			
FFTF (USA)	15	18	20	
BR-10 (Russia)	1-3			
CEFR (China)	33***		25	

Demonstration or Prototype Fast Reactors

Phénix (France)	15	13	25	10
SNR-300 (Germany)	25	25	100	6
PFBR (India)			4	5
MONJU (Japan)	20	20	100	20
PFR (UK)	30	25	20	6
CRBRP (USA)	all fuel and inner blanket assemblies replaced every two cycles (2 years)			
BN-350 (Kazakhstan)	20	15	25	15
BN-600 (Russia)	33.3	33.3	50	25
ALMR (USA)	25	25	33	

Commercial Size Reactors

Super-Phénix 1 (France)	****			
Super-Phénix 2 (France)	20	20		17
SNR 2 (Germany)	33.3	33.3	50	16.7
DFBR (Japan)	33.3	33.3	100	33.3
CDFR (UK)	33	30	20	12
BN-1600 (Russia)	25	25		25
BN-800 (Russia)	33.3	33.3	50	25
EFR	20	20	33.3/20**	12.5
ALMR(USA)	33	33	33	25

* MK-II; (according mainly to the PIE plan in MK-I, 75 MWth)

** Control and shutdown rods / Diverse shutdown rods

*** 25 and 7 later

**** not completely defined.

CORE CHARACTERISTICS

- 3.10. Total breeding gain*
 3.11. Breeding gain: core regions only

Experimental Fast Reactors

Plant	3.10.	3.11.
Rapsodie (France)		
KNK-II (Germany)		
FBTR (India)		
PEC (Italy)		
JOYO (Japan)	0.06 (MK-I)	
DFR (UK)		
BOR-60 (Russia)		
EBR-II (USA)		configuration not for breeding
Fermi (USA)		0.16
FFTF (USA)		configuration not for breeding
BR-10 (Russia)		configuration not for breeding
CEFR (China)		configuration not for breeding

Demonstration or Prototype Fast Reactors

Phénix (France)	0.16	
SNR-300 (Germany)	0.10 (MK II)	
PFBR (India)	0.1	
MONJU (Japan)	0.2	
PFR (UK)	-0.05	
CRBRP (USA)	0.24 (0.29 for initial core)	
BN-350 (Kazakhstan)	0	
BN-600 (Russia)	-0.15	
ALMR (USA)		configuration not for breeding

Commercial Size Reactors

Super-Phénix 1 (France)	0.18	
Super-Phénix 2 (France)		
SNR 2 (Germany)	0.12	
DFBR (Japan)	0.2	
CDFR (UK)	0.15	
BN-1600 (Russia)	0.1	
BN-800 (Russia)	-0.02	
EFR	0.02	-0.2
ALMR (USA)	0.23	

* Breeding gain is defined as: $BG = \frac{W_i(C_i - D_i)}{F_i}$

C_i and D_i - respectively rates of creation and destruction of atoms of i

W_i - the worth of atoms of i , relative to Pu239 atoms

F_i - the total fission rate

CORE CHARACTERISTICS

- 3.12. Reactivity coefficients
- 3.12.1. Isothermal temperature coefficient (pcm/°C) at full power
- 3.12.2. Total power coefficient of reactivity (pcm/MWth) at full power, constant inlet temperature
- 3.12.3. Maximum sodium void effect (dollars), including only regions with a positive sodium reactivity worth

Experimental Fast Reactors

Plant	3.12.1.	3.12.2.	3.12.3.
Rapsodie (France)	-4.5	-6.0 (equilibrium)	
KNK-II (Germany)	-5 (-4.7*)	-8 (-7.9*)	-2.4 (-3.2*)
FBTR (India)	-4.8 (-4.5*)	-19 (-35*)	-20.57
PEC (Italy)	-3.5 (-3.3*)	-2.5 (-4.3*)	+0.2
JOYO (Japan)	-2.7**	-6.3**	-4.1**
DFR (UK)	-5.4	-6.7	0
BOR-60 (Russia)	-4.0	-8.0	-8.0
EBR-II (USA)	-3.6	-4.2	
Fermi (USA)	-0.39	-0.20	
FFTF (USA)	-1.08	-0.4	-13
BR-10 (Russia)	-2.2	-8.2	-6.1
CEFR (China)	-4.77	-8.60	-9.73

Demonstration or Prototype Fast Reactors

Phénix (France)	-2.7	-0.5	
SNR-300 (Germany)	-2.3	-0.3	+2.9
PFBR (India)	-2.6	-0.76	+3.5
MONJU (Japan)	-2.0	-09.4 to 1.1	
PFR (UK)	-3.3	-1.7	+2.6
CRBRP (USA)	-0.63	-0.2	+2.29 (end of cycle 4)
BN-350 (Kazakhstan)	-1.9	-0.7	-0.6***
BN-600 (Russia)	-1.7	-0.6	-0.3***
ALMR (USA)			4.0

Commercial Size Reactors

Super-Phénix 1 (France)	-2.75	-0.1	+5.9
Super-Phénix 2 (France)			
SNR 2 (Germany)			
DFBR (Japan)			+4.0
CDFR (UK)	-0.20	-0.16	+5.7
BN-1600 (Russia)	-1.6	-0.1	~0***
BN-800 (Russia)	-1.7	-0.36	~0***
EFR	-1.1	-0.12	+6.4
ALMR (USA)			+6.5

* for free fuel instead of bound fuel

** MK-II; (-3.8, -6.2, -9.0, respectively, in MK-I, 75 MWth)

*** Core and upper part of subassemblies

CORE CHARACTERISTICS

- 3.12. Reactivity coefficients
- 3.12.4. Doppler coefficient (Tdk/dt):
- 3.12.4.1. for voided core
- 3.12.4.2. for unvoided core

Experimental Fast Reactors

Plant	3.12.4.1.	3.12.4.2.
Rapsodie (France)	0	0
KNK-II (Germany)		-0.0030
FBTR (India)	0.0	0.0
PEC (Italy)	-0.002	-0.003
JOYO (Japan)	-0.0014	-0.0017
DFR (UK)		0.0002
BOR-60 (Russia)		
EBR-II (USA)	value is very small, approximately -0.0003, sodium-in; therefore no sodium-out calculations have been made	
Fermi (USA)		-0.00026
FFTF (USA)	-0.003	-0.005
BR-10 (Russia)	0	0
CEFR (China)	-0.0021	-0.0025

Demonstration or Prototype Fast Reactors

Phénix (France)	-0.004	-0.006
SNR-300 (Germany)	-0.003	-0.004
PFBR (India)	-0.003	-0.0055
MONJU (Japan)		-0.0057 to -0.0076
PFR (UK)	-0.0040	-0.0068
CRBRP (USA)	-0.00166	-0.00258
BN-350 (Kazakhstan)	-0.0049	-0.007
BN-600 (Russia)	-0.0044	-0.007
ALMR (USA)	-0.0017	-0.0028

Commercial Size Reactors

Super-Phénix 1 (France)	-0.007	-0.009
Super-Phénix 2 (France)		
SNR 2 (Germany)		
DFBR (Japan)		-0.008
CDFR (UK)	-0.0056	-0.0080
BN-1600 (Russia)		-0.007
BN-800 (Russia)	-0.004	-0.007
EFR	-0.005	-0.0065
ALMR (USA)	-0.0026	-0.0044