5. CONTROL RODS AND DRIVE MECHANISMS

5.1. No. of safety (shut down) rods
5.2. No. of regulating rods (or combined regulating and safety rods)
5.2.1. No. of group 1 regulating rods, sometimes designated "fine rods"
5.2.2. No. of group 2 regulating rods, sometimes designated "coarse rods"
5.3. No. of rods contributing to rapid shutdown within the first and second shutdown systems
5.4. No. of additional, diverse, shutdown rods or devices (not included in 5.3)

Experimental Fast Reactors

Plant	5.1.	5.2.1.	5.2.2.	5.3.	5.4.
Rapsodie (France)	6	6	5	6	
KNK-II (Germany)	8				
FBTR (India)	6	6	0		
PEC (Italy)		11		11	
JOYO (Japan)		6		6	
DFR (UK)	9	0	6	15	
BOR-60 (Russia)	3	2	2		
EBR-II (USA)	2				
Fermi (USA)	8	2			
FFTF (USA)	9	3	6		
BR-10 (Russia)	2 MRR*	2 (Ni)	1 MRR	2	
CEFR (China)	2	2	4	8	

Demonstration or Prototype Fast Reactors

Phénix (France)	6 (Safety and Regulating)				
SNR-300 (Germany)	12	1	8		
PFBR (India)	3	9			
MONJU (Japan)	6	3	10		
PFR (UK)	5	0	5	10	
CRBRP (USA)	15	9	6		
BN-350 (Kazakhstan)	3	2	7	5	
BN-600 (Russia)	6	2	19	8	
ALMR (USA)		9			6GEM** + 3 Ultimate***

Commercial Size Reactors

Super-Phénix 1 (France)	24	21		21	3
Super-Phénix 2 (France)	27				
SNR 2 (Germany)	25 + 12 (articulated)				
DFBR (Japan)	30				
CDFR (UK)	12	0	18		
BN-1600 (Russia)	12	2	23	37	
BN-800 (Russia)	12	2	16	12	3 HSRs****
EFR*****	33	5+12	4+12	33	
ALMR (USA)		9			6GEM** + 3 Ultimate***

* MRR - movable ring reflector (Ni)
** GEM - gas expansion module
*** The ultimate system injects B_4C balls (see 5.9.11)
**** HSR - hydraulically suspended rod
***** Diverse shutdown rods + control and shutdown rods

5.5. Absorber pins
5.5.1. No. of absorber pins per control rod: safety rods
5.5.2. No. of absorber pins per control rod: Group 1 rods
5.5.3. No. of absorber pins per control rod: Group 2 rods

Experimental Fast Reactors

Plant	5.5.1.	5.5.2.	5.5.3.
Rapsodie (France)	1		
KNK-II (Germany)	55		55
FBTR (India)	1		
PEC (Italy)	7	7	7
JOYO (Japan)	7*	*	
DFR (UK)	1		10**
BOR-60 (Russia)	7	4	7
EBR-II (USA)			
Fermi (USA)	6	19	
FFTF (USA)		61	61
BR-10 (Russia)			
CEFR (China)	7	7	7

Demonstration or Prototype Fast Reactors

Phénix (France)	7		
SNR-300 (Germany)	19	19	19
PFBR (India)	19		
MONJU (Japan)	19	19	19
PFR (UK)	19		19
CRBRP (USA)		37	31
BN-350 (Kazakhstan)	7	7	85
BN-600 (Russia)	7	31	8
ALMR (USA)		61	

Commercial Size Reactors

Super-Phénix 1 (France)	31/16****	31	
Super-Phénix 2 (France)	20 or 31		
SNR 2 (Germany)	55 (articulated)	61	
DFBR (Japan)	31		
CDFR (UK)	19		19
BN-1600 (Russia)	to be determined		
BN-800 (Russia)	7	7	7
EFR	37/55***	37/55***	37/55***
ALMR (USA)		61	

* MK-II; (7,7 (fine and coarse), respectively, in MK-I)
** fuel pins
*** control and shutdown rods / Diverse shutdown rods
**** diverse shutdown rods

5.5.4. Outer diameter of absorber pin (mm): safety
5.5.5. Group 1
5.5.6. Group 2

Experimental Fast Reactors

Plant	5.5.4.	5.5.5.	5.5.6.
Rapsodie (France)	45.0		
KNK-II (Germany)	10.3	10.3	
1FBTR (India)			
PEC (Italy)	17.7	17.7	17.7
JOYO (Japan)	18.1*	*	
DFR (UK)	23.0		20.00**
BOR-60 (Russia)	12.0	12.0	12.0
EBR-II (USA)			
Fermi (USA)	15.9	7.9	
FFTF (USA)	12.0	12.0	
BR-10 (Russia)			
CEFR (China)	14.9	14.9	14.9

Demonstration or Prototype Fast Reactors

Phénix (France)	28.0		
SNR-300 (Germany)	15.5	15.5	15.5
PFBR (India)			
MONJU (Japan)	17.0	17.0	17.0
PFR (UK)	22.0		22.0
CRBRP (USA)		15.3	14.0
BN-350 (Kazakhstan)	23.0	9.5	6.9
BN-600 (Russia)	23.0	9.5	23.0
ALMR (USA)		16.7	

Commercial Size Reactors

Super-Phénix 1 (France)	21/53, 26.7****	21.0	
Super-Phénix 2 (France)			
SNR 2 (Germany)		17.6	
DFBR (Japan)	20.0		
CDFR (UK)	22.0		22.0
BN-1600 (Russia)	to be determined		
BN-800 (Russia)	23.0	23.0	23.0
EFR	22.78/16.35***	22.78/16.35***	22.78/16.35***
ALMR (USA)		16.7	

* MK-II; (17.6 (fine and coarse) in MK-I)
** the reactor was controlled by movement of fuel pins in triangular clusters
*** control and shutdown rods / Diverse shutdown rods
**** diverse shutdown rods

5.5.7. Material of neutron absorber : safety
5.5.8. group 1
5.5.9. group 2

[If B_4C is used it is abbreviated below as BCx, where x is the enrichment ($\%B^{10}$) and if boron powder or sintered powder is used it is abbreviated as Bx]

Experimental Fast Reactors

Plant	5.5.7.	5.5.8.	5.5.9.
Rapsodie (France)	BC90	BC90	
KNK-II (Germany)		BC93	
FBTR (India)	BC90	BC90	
PEC (Italy)		BC90	
JOYO (Japan)		BC90	
DFR (UK)	B80	Fuel	
BOR-60 (Russia)	BC80	BC80	Eu_2O_3
EBR-II (USA)	Fuel	Fuel + BC followers	
Fermi (USA)	BC	BC	
FFTF (USA)	B20.	B20	B20
BR-10 (Russia)			
CEFR (China)	BC91	BC91	BC91

Demonstration or Prototype Fast Reactors

Phénix (France)	BC48	BC48	BC48
SNR-300 (Germany)	BC47	BC47	BC47
PFBR (India)	BC50	BC50	BC50
MONJU (Japan)	BC90	BC39	BC39
PFR (UK)	BC40	BC20	BC20
CRBRP (USA)	BC92	BC92	BC92
BN-350 (Kazakhstan)	BC80	BC60	UO_2 enriched/UO_2 depleted
BN-600 (Russia)	BC80	BC20	BC20
ALMR (USA)		BC92	

Commercial Size Reacotrs

Super-Phénix 1 (France)	BC90	BC90	
Super-Phénix 2 (France)	BC90	BC90	BC90
SNR 2 (Germnay)		B90	B90
DFBR (Japan)	BC92		
CDFR (UK)	BC30		BC20
BN-1600 (Russia)	BC80	BC80	BC80
BN-800 (Russia)	BC92	BC20	BC20
EFR	BC30, 45, 90	BC30,45,90	BC30, 90*
ALMR (USA)		BC20	

* Control and shutdown rods / Diverse shutdown rods

5.6. Worth of control rod (% ΔK/K)
5.6.1. Safety (total)
5.6.2. Group 1 (total)
5.6.3. Group 1 (per rod)
5.6.4 Group 2 (total)
5.6.5 Total reactivity worth of all rods moving over whole range

Plant	5.6.1.	5.6.2.	5.6.3.	5.6.4.	5.6.5.
Experimental Fast Reactors					
Rapsodie (France)	10.0			15.0	
KNK-II (Germany)	4.5				
FBTR (India)	6.92				
PEC (Italy)	6.8				6.8
JOYO (Japan)	13.0	13.0	2.2	13.0	
DFR (UK)	8.0			8.0	
BOR-60 (Russia)	3.2	0.4	0.2	2.8	
EBR-II (USA)	1,0 B_{ef}	3.7 B_{ef}	0.8 B_{ef}*		
Fermi (USA)	9.2 B_{ef}	0.92			
FFTF (USA)		6.3	8.4		
BR-10 (Russia)	5.1	0.18	0.09	5.1	5.1
CEFR (China)	4.092	0.786	0.393	4.881	10.08
Demonstration Prototype Fast Reactors					
Phénix (France)	8.0				
SNR-300 (Germany)	2.9	7.3	0.8		
PFBR (India)	7.2				
MONJU (Japan)	5.8				7.00**
PFR (UK)	2.0			7.0	
CRBRP (USA)		22.2 B_{ef}	12.8 B_{ef}		
BN-350 (Kazakhstan)	3.5	0.5	0.25	3.2	
BN-600 (Russia)	2.9	0.48	0.24	7.0	
ALMR (USA)	9.3				
Commercial Size Reactors					
Super-Phénix 1 (France)	10.0	8.5	0.4		10.0
Super-Phénix 2 (France)	12.0				
SNR 2 (Germany)	2.9	8.5	0.4		
DFBR (Japan)	8.9 + 1.6				
CDFR (UK)	4.0			5.0	
BN-1600 (Russia)	2.8	0.4	0.2	6.7	
BN-800 (Russia)	4.1	0.4	0.2	6.1	9.0
EFR***	10.3	8.1	0.34		10.3
ALMR (USA)	6.8				

* with boron follower (0.38 B_{ef} -- without boron follower)
** group 1 and 2 with one rod stuck
*** diverse shutdown

5.7. Vertical travel of control rod (mm)
5.7.1. Safety
5.7.2. Group 2
5.7.3. Group 1

Experimental Fast Reactors

Plant	5.7.1.	5.7.2.	5.7.3.
Rapsodie (France)	450		
KNK-II (Germany)	670		620
FBTR (India)	450		450
PEC (Italy)	750	750	750
JOYO (Japan)	650*	*	
DFR (UK)	700	600	
BOR-60 (Russia)	450	450	400
EBR-II (USA)	361	361	361
Fermi (USA)	1370		508
FFTF (USA)	940	940	940
BR-10 (Russia)	300-340	300-340	280
CEFR (China)	550	550	550

Demonstration Prototype Fast Reactors

Phénix (France)	900		
SNR-300 (Germany)	1050		830
PFBR (India)	1085		
MONJU (Japan)	1100	1000	1000
PFR (UK)	1320	1070	
CRBRP (USA)	914-960	952	
BN-350 (Kazakhstan)	1260	1060	750
BN-600 (Russia)	900	900	750
ALMR (USA)	914	***	

Commercial Size Reactors

Super-Phénix 1 (France)	1100		1100
Super-Phénix 2 (France)	1250	1250	1250
SNR 2 (Germany)	1200	1200	1200
DFBR (Japan)	1000		
CDFR (UK)	1150	1000	
BN-1600 (Russia)	900	900	900
BN-800 (Russia)	1030	870	870
EFR	1000/945**	1000/945**	1000/945**
ALMR (USA)	to be determined		

* MK-II; 900, 700 (fine and coarse), respectively, in MK-I
** Control and shutdown rods / diverse shutdown rods
*** By B_4C ball injection system

5.8. Rod-drop time, designed (seconds)
5.8.1. Safety
5.8.2. Group 2
5.8.3. Group 1

Experimental Fast Reactors

Plant	5.8.1.	5.8.2.	5.8.3.
Rapsodie (France)	0.4		
KNK-II (Germany)	0.3		
FBTR (India)	0.4		0.4
PEC (Italy)	0.5	0.5	0.5
JOYO (Japan)	0.8		
DFR (UK)	0.4	0.35	
BOR-60 (Russia)	0.5	200	
EBR-II (USA)	1.0	0.450	
Fermi (USA)	0.9		46
FFTF (USA)	0.935	0.935	
BR-10 (Russia)	0.4	0.4	
CEFR (China)	0.7	1.2	1.2

Demonstration Prototype Fast Reactors

Phénix (France)	0.7		
SNR-300 (Germany)	0.55	0.56	0.56
PFBR (India)	0.7		
MONJU (Japan)	less than 1.2	less than 1.2	less than 1.2
PFR (UK)	0.5	0.45	
CRBRP (USA)		1.0	1.8
BN-350 (Kazakhstan)	0.7	220	5
BN-600 (Russia)	1.0	160	11
ALMR (USA)	1.0	120	

Commercial Size Reactors

Super-Phénix 1 (France)	0.8		0.8
Super-Phénix 2 (France)	1.0	1.0	1.0
SNR 2 (Germany)	0.8	0.8	
DFBR (Japan)	less than 1.2		
CDFR (UK)	1.0	0.8	
BN-1600 (Russia)	to be determined		
BN-800 (Russia)	1.0	174	13.0
EFR	0.7/0.7*	0.7/0.7*	0.7/0.7*
ALMR (USA)	1.0	120	

* Control and shutdown rods / Diverse shutdown rods

5.9. Features of drive mechanism
5.9.1. Safety

Experimental Fast Reactors

Plant	5.9.1.
Rapsodie (France)	screw drive with magnetic hold-up
KNK-II (Germany)	
FBTR (India)	screw drive with magnetic hold-up
PEC (Italy)	electro-magnetic
JOYO (Japan)	motor drive/spring accleration
DFR (UK)	screw drive gear with magnetic hold-up
BOR-60 (Russia)	gravity and spring assist
EBR-II (USA)	safety rods are pulled out of core by heavy yoke at bottom, upon manual release
Fermi (USA)	
FFTF (USA)	electro-mechanical linear actuating
BR-10 (Russia)	gravity
CEFR (China)	ball-screw drive gear with magnetic hold-up, spring acceleration

Demonstration Prototype Fast Reactors

Phénix (France)	mechanical + electro-mechanical
SNR-300 (Germany)	screw drive gear with magnetic hold-up (1st), spring acceleration (2nd)
PFBR (India)	screw drive with magnetic hold-up
MONJU (Japan)	motor drive/spring acceleration
PFR (UK)	screw drive gear with magnetic hold-up
CRBRP (USA)	primary: collapsible roller-nut drive; spring assisted gravity insertion
BN-350 (Kazakhstan)	rack drive gear with magnetic hold-up
BN-600 (Russia)	rack drive gear with magnetic hold-up and accelerating spring
ALMR (USA)	B_4C balls released into open thimble at core center

Commercial Size Reactors

Super-Phénix 1 (France)	rack drive gear with magnetic hold-up/electro magnet in sodium*
Super-Phénix 2 (France)	mechanical + electro-mechanical
SNR 2 (Germany)	1. electro-magnet in gas 2. electro-magnet in sodium
DFBR (Japan)	screw drive gear with magnetic hold-up and SASS**
CDFR (UK)	screw drive gear with magnetic hold-up
BN-1600 (Russia)	rack drive gear with magnetic hold-up and accelerating spring
BN-800 (Russia)	rack drive gear with magnetic hold-up and accelerating spring
EFR	1. electro magnet in gas 2. electro magnet in sodium
ALMR (USA)	B_4C balls released into open thimble at core centre

* diverse shutdown rods
** SSAS - a pssive shutdown system (Curie point magnets)

5.9. Features of drive mechanism
5.9.2. Coarse
5.9.3. Fine

Experimental Fast Reactors

Plant	5.9.2.	5.9.3.
Rapsodie (France)		
KNK-II (Germany)	falling	
FBTR (India)		
PEC (Italy)	electro-magnetic	electro-magnetic
JOYO (Japan)	*	*
DFR (UK)	screw drive gear with magnetic hold up	
BOR-60 (Russia)		
EBR-II (USA)	control rods actuated manually or automatically use air-assist and dashpot system to optimize velocity of stroke	
Fermi (USA)		ball-nut-and-screw
FFTF (USA)	electro-mechanical linear actuating	electro-mechanical linear actuating
BR-10 (Russia)	electro-mechanical	electro-mechanical
CEFR (China)	ball-screw and magnetic	ball-screw and magnetic

Demonstration Prototype Fast Reactors

Phénix (France)	mechanical and electro-mechanical	
SNR-300 (Germany)	screw drive gear with magnetic hold up	
PFBR (India)	not yet determined	
MONJU (Japan)	motor drive/gas pressure acceleration (for both)	
PFR (UK)	screw drive gear with magnetic hold up	
CRBRP (USA)	secondary: ball-nut screw drive; hydraulic assisted insertion; coarse (fixed shim rods): none	
BN-350 (Kazakhstan)	screw drive gear	screw drive gear
BN-600 (Russia)	rack drive gear	rack drive gear
ALMR (USA)	ball-nut screw drive; motor-assisted drive in; fine motion control	

Commercial Size Reactors

Super-Phénix 1 (France)	rack drive gear with magnetic - hold up	
Super-Phénix 2 (France)	mechanical and electro-mechanical	
SNR 2 (Germany)	screw drive gear with magnetic hold up	
DFBR (Japan)	not yet determined	
CDFR (UK)	screw drive gear with magnetic hold up	
BN-1600 (Russia)	rack drive gear	rack drive gear
BN-800 (Russia)	rack drive gear	rack drive gear
EFR	mechanical and electro-mechanical	mechanical and electro-mechanical
ALMR (USA)	ball-nut screw drive; motor assisted drive in, fine motion control	

* Mk-II (motor drive / spring acceleration in Mk-I)