7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM

7.1. Reactor vessel (primary tank)

Experimental Fast Reactors

Plant	Reactor vessel (primary tank)			
	Dimension (mm)			Material
	Inside diameter	Thickness (minimum/ maximum)	Inside height	
Rapsodie (France)	2350	15		316
KNK-II (Germany)	1870	16	10150	1.6770
FBTR (India)	2350	15	-	316
PEC (Italy)	3080	30	10300	316
JOYO (Japan)	3600	25	10000	304
DFR (UK)	3200	12	6300	18/8/1
BOR-60 (Russian Federation)	1400	20	6200	Cr 18 Ni9
EBR-II (USA)	7920	19	3960	304
Fermi (USA)	4800(2800**)	50	11000	304
FFTF (USA)	6170	70	13130	304
BR-10 (Russian Federation)	338	7	4500	Cr 18 Ni 9
CEFR (China)	7960	25/50	12195	316

Demonstration or Prototype Fast Reactors

Phénix (France)	11820	15	12000	316
SNR-300 (Germany)	6700		15000	1.4948*
PFBR (India)	12850	25/40	12920	316LN
MONJU (Japan)	7100	50	17800	304
PFR (UK)	12200	25/50	15200	321
CRBRP (USA)	6170	60	17920	304
BN-350 (Kazakhstan)	6000	50	11900	Cr 18 Ni 9
BN-600 (Russian Federation)	12860	30	12600	Cr 18 Ni 9
ALMR (USA)	9118	51	19355	316
KALIMER-150 (Republic of Korea)	6920	50	18425	316
SVBR-75/100 (Russian Federation)	4130	35	7000	Cr 18 Ni 9
BREST-OD-300 (Russian Federation)	6800	40	14140	Cr 16 Ni 10

* 304 SS

** lower section

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.1. Reactor vessel (primary tank)

Commercial Size Reactors

Plant	Reactor vessel (primary tank)			
	Dimension (mm)			Material
	Inside diameter	Thickness (minimum/ maximum)	Inside height	
Super-Phénix 1 (France)	21000	25/60	17300	316
Super-Phénix 2 (France)	20000	20/35	16200	316
SNR 2 (Germany)	15000	-	-	304
DFBR (Japan)	10400	50	16000	316 FR
CDFR (UK)	19220	25	18100	316
BN-1600 (Russian Federation)	17000	25	14000	Cr 18 Ni 9
BN-800 (Russian Federation)	12900	30	14000	Cr 18 Ni 9
EFR	17200	35	15900	316
ALMR (USA)	9118	51	19355	316
SVBR-75/100 (Russian Federation)	4130	35	7000	Cr 18 Ni 9
BN-1800 (Russian Federation)	17000	25	19950	Cr 18 Ni 9
BREST-1200 (Russian Federation)	9000	50	~ 18600	Cr 16 Ni 10
JSFR-1500 (Japan)	10700	30	21200	316 FR

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps	
	Electrical (E) or Mechanical (M)	Main features
Rapsodie (France)	M	centrifugal
KNK-II (Germany)	M	centrifugal
FBTR (India)	M	centrifugal single section
PEC (Italy)	M	free surface centrifugal
JOYO (Japan)	M	single stage centrifugal
DFR (UK)	E	-
BOR-60 (Russian Federation)	M	centrifugal
EBR-II (USA)	-	centrifugal
Fermi (USA)	M	centrifugal
FFTF (USA)	M	free surface centrifugal
BR-10 (Russian Federation)	E	-
CEFR China)	M	centrifugal

Demonstration or Prototype Fast Reactors

Phénix (France)	-	single stage
SNR-300 (Germany)	-	centrifugal, single section
PFBR (India)	M	centrifugal, single stage, free surface, top suction
MONJU (Japan)	M	single stage centrifugal
PFR (UK)	M	centrifugal, double entry
CRBRP (USA)	M	free surface centrifugal
BN-350 (Kazakhstan)	M	centrifugal
BN-600 (Russian Federation)	M	centrifugal
ALMR (USA)	E	submersible, double statar, self cooled
KALIMER-150 (Republic of Korea)	E	submersible, double stator, self cooled
SVBR-75/100 (Russian Federation)	M	centrifugal, submersible
BREST-OD-300 (Russian Federation)	M	axial single section

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Fast Reactors

Plant	Main pumps	
	Electrical (E) or Mechanical (M)	Main features
Super-Phénix 1 (France)	M	single stage
Super-Phénix 2 (France)	M	single stage
SNR 2 (Germany)	-	centrifugal
DFBR (Japan)	M	single stage centrifugal
CDFR (UK)	M	centrifugal, multi-entry
BN-1600 (Russian Federation)	M	centrifugal
BN-800 (Russian Federation)	M	centrifugal
EFR	M	single stage centrifugal
ALMR (USA)	E	submersible, double stator, self cooled
SVBR-75/100 (Russian Federation)	M	centrifugal, submersible
BN-1800 (Russian Federation)	M	centrifugal
BREST-1200 (Russian Federation)	M	axial single section
JSFR-1500 (Japan)	M	single stage centrifugal

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps			
	Location		Pump capacity (m^3/min)	
	Primary	Secondary	Primary	Secondary
Rapsodie (France)	cold leg	hot leg	10.2	9.4
KNK-II (Germany)	hot leg	cold leg	10	8.6
FBTR (India)	cold leg	cold leg	11.0	6.2
PEC (Italy)	cold leg	cold leg	22.1(0.6*)	21.9 (1.1*)
JOYO (Japan)	cold leg	cold leg	26x2**	23x2***
DFR (UK)	cold leg	cold leg	1.3	1.3
BOR-60 (Russian Federation)	cold leg	cold leg	10	~ 14.0
EBR-II (USA)	cold leg	cold leg	34.1	22.3
Fermi (USA)	cold leg	cold leg	45	49
FFTF (USA)	hot leg	cold leg	56	56
BR-10 (Russian Federation)	cold leg	cold leg	3.3	3.3
CEFR (China)	cold leg	cold leg	14.25	9.5

Demonstration or Prototype Fast Reactors

Phénix (France)	cold leg	cold leg	63	52
SNR-300 (Germany)	hot leg	cold leg	86	76
PFBR (India)	cold leg	cold leg	247.8	200.4
MONJU (Japan)	cold leg	cold leg	100	71
PFR (UK)	cold leg	cold leg	84	75
CRBRP (USA)	hot leg	cold leg	130	115
BN-350 (Kazakhstan)	cold leg	cold leg	53.3	63.3
BN-600 (Russian Federation)	cold leg	cold leg	161.71	133.3
ALMR (USA)	cold leg	cold leg	82.5	151.7
KALIMER-150 (Republic of Korea)	cold leg	cold leg	35	62.14
SVBR-75/100 (Russian Federation)	cold leg	-	34.2	-
BREST-OD-300 (Russian Federation)	cold leg	-	72x4	-

* test channel
** 21x2 in MK-I, II
*** 21x2 in MK-I, II

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Fast Reactors

Plant	Main pumps			
	Location		Pump capacity (m^3/min)	
	Primary	Secondary	Primary	Secondary
Super-Phénix 1 (France)	cold leg	cold leg	290	230
Super-Phénix 2 (France)	cold leg	cold leg	350	270
SNR 2 (Germany)	hot leg	cold leg		
DFBR (Japan)	cold leg	cold leg	191	156
CDFR (UK)	cold leg	cold leg	310	300
BN-1600 (Russian Federation)	cold leg	cold leg	487	190
BN-800 (Russian Federation)	cold leg	cold leg	205	192
EFR	cold leg	cold leg	450	177
ALMR (USA)	cold leg	cold leg	82.5	151.7
SVBR-75/100 (Russian Federation)	cold leg	-	34.2	-
BN-1800 (Russian Federation)	cold leg	cold leg	-	-
BREST-1200 (Russian Federation)	cold leg	-	228.5x4	-
JSFR-1500 (Japan)	cold leg	cold leg	630x2	512x2

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps	
	Pump head (MPa)	
	Primary	Secondary
Rapsodie (France)	0.46	0.25
KNK-II (Germany)	-	-
FBTR (India)	0.46	0.3
PEC (Italy)	0.55 (1.24*)	0.2 (0.1*)
JOYO (Japan)	0.51**	0.35***
DFR (UK)	0.175	0.175
BOR-60 (Russian Federation)	0.85	0.6
EBR-II (USA)	0.386	-
Fermi (USA)	1.03	0.40
FFTF (USA)	1.01	0.81
BR-10 (Russian Federation)	0.3	0.3
CEFR (China)	0.38	0.35

Demonstration or Prototype Fast Reactors

Phénix (France)	0.5	0.4
SNR-300 (Germany)	0.685	0.833
PFBR (India)	0.63	0.55
MONJU (Japan)	0.8	0.5
PFR (UK)	0.8	0.4
CRBRP (USA)	1.12	0.86
BN-350 (Kazakhstan)	0.94	0.58
BN-600 (Russian Federation)	0.81	0.31
ALMR (USA)	0.76	0.34
KALIMER-150 (Republic of Korea)	0.8	0.4
SVBR-75/100 (Russian Federation)	0.55	-
BREST-OD-300 (Russian Federation)	0.225	-

* test channel
** 0.63 in MK-I, II
*** 0.37 in MK-I, II

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Fast Reactors

Plant	Main pumps	
	Pump head (MPa)	
	Primary	Secondary
Super-Phénix 1 (France)	0.53	0.25
Super-Phénix 2 (France)	-	-
SNR 2 (Germany)	-	-
DFBR (Japan)	0.8	0.48
CDFR (UK)	1.0	0.6
BN-1600 (Russian Federation)	0.5	0.331
BN-800 (Russian Federation)	0.82	0.42
EFR	0.6	0.457
ALMR (USA)	0.76	0.34
SVBR-75/100 (Russian Federation)	0.55	-
BN-1800 (Russian Federation)	~ 0.8	~ 0.4
BREST-1200 (Russian Federation)	0.2	-
JSFR-1500 (Japan)	0.639	0.335

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps			
	Speed (rev./min.)			
	Primary (nominal)	Secondary (nominal)	Primary (decay heat removal made using standby-supplies)	Secondary (decay heat removal made using standby-supplies)
Rapsodie (France)	1250	1000	-	-
KNK-II (Germany)	1430	1430	-	-
FBTR (India)	1500	1450	100	100
PEC (Italy)	681	1150	-	-
JOYO (Japan)	930	1060*	130 and EM pump	
DFR (UK)	-	-	-	-
BOR-60 (Russian Federation)	1200	1200	natural circulation	
EBR-II (USA)	880	-	-	-
Fermi (USA)	875	900	70	85
FFTF (USA)	1100	1110	110	110
BR-10 (Russian Federation)	-	-	-	-
CEFR (China)	990	900	150	150

Demonstration or Prototype Fast Reactors

Phénix (France)	820	800	100	100
SNR-300 (Germany)	960	960	-	-
PFBR (India)	590	900	89	-
MONJU (Japan)	850	1100	-	
PFR (UK)	950	950	96	0
CRBRP (USA)	1170	963	93	93
BN-350 (Kazakhstan)	1000	1000	250	250
BN-600 (Russian Federation)	1000	1000	250	250
ALMR (USA)	EM pumps		natural circulation	
KALIMER-150 (Republic of Korea)	EM pumps		natural circulation	
SVBR-75/100 (Russian Federation)	750	-	-	-
BREST-OD-300 (Russian Federation)	368	none	natural circulation	

* 975 in MK-I, II

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Fast Reactors

Plant	Main pumps			
	Speed (rev./min.)			
	Primary (nominal)	Secondary (nominal)	Primary (decay heat removal made using standby-supplies)	Secondary (decay heat removal made using standby-supplies)
Super-Phénix 1 (France)	433	470	75	110
Super-Phénix 2 (France)	-	-	-	-
SNR 2 (Germany	-	-	-	-
DFBR (Japan)	855	875	128	114
CDFR (UK)	360	500	36	0
BN-1600 (Russian Federation)	600	1000	150	250
BN-800 (Russian Federation)	990	990	250	250
EFR	530	780	132.5	117
ALMR (USA)	EM pumps		natural circulation	
SVBR-75/100 (Russian Federation)	750	-	-	-
BN-1800 (Russian Federation)	600	-	natural circulation	
BREST-1200 (Russian Federation)	to be determined		natural circulation	
JSFR-1500 (Japan)	554	522	83	78

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps			
	Main pumps rating (kW)			
	Electrical power input			
	Primary (nominal)	Secondary (nominal)	Primary (under decay heat removal made using standby-supplies)	Secondary (under decay heat removal made using standby-supplies)
Rapsodie (France)	120	54	-	-
KNK-II (Germany)	-	-	-	-
FBTR (India)	150	55	2.5	-
PEC (Italy)	565 (73*)	155 (182*)	-	-
JOYO (Japan)	330	220	2.5	-
DFR (UK)	400	400	-	-
BOR-60 (Russian Federation)	285	-	-	-
EBR-II (USA)	260	-	-	-
Fermi (USA)	1000	350	-	-
FFTF (USA)	1520	1110	4.3	5.8
BR-10 (Russian Federation)	38	38	2.7	-
CEFR (China)	150	150	2	2

Demonstration or Prototype Fast Reactors

Phénix (France)	800	500	-	2
SNR-300 (Germany)	2400	1600	-	-
PFBR (India)	3600	2600	19	-
MONJU (Japan)	2000	800	22	22
PFR (UK)	4920	2010	18	0
CRBRP (USA)	3940	3940	18.6	18.6
BN-350 (Kazakhstan)	1700	1100	55	35
BN-600 (Russian Federation)	3150	1330	277	52
ALMR (USA)	1708	1448	-	-
KALIMER-150 (Republic of Korea)	850	850	to be determined	-
SVBR-75/100 (Russian Federation)	420	-	-	-
BREST-OD-300 (Russian Federation)	500	-	-	-

* test channel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Reactors

Plant	Main pumps			
	Main pumps rating (kW)			
	Electrical power input			
	Primary (nominal)	Secondary (nominal)	Primary (under decay heat removal made using standby-supplies)	Secondary (under decay heat removal made using standby-supplies)
Super-Phénix 1 (France)	4170	1620	36	30
Super-Phénix 2 (France)	4500	2000	-	-
SNR 2 (Germany)	-	-	-	-
DFBR (Japan)	3400	900	to be determined	
CDFR (UK)	5500	4500	23	0
BN-1600 (Russian Federation)	6500	1500	150	75
BN-800 (Russian Federation)	4300	2000	250	-
EFR	to be determined	1660	to be determined	
ALMR (USA)	1708	1448	-	-
SVBR-75/100 (Russian Federation)	420	-	-	-
BN-1800 (Russian Federation)	7850	-	to be determined	
BREST-1200 (Russian Federation)	to be determined	-	-	-
JSFR-1500 (Japan)	9300	4000	to be determined	

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps	
	Principle of speed control	Operating range of speed control (% nominal flow)
Rapsodie (France)	Ward Leonard drive	-
KNK-II (Germany)	-	-
FBTR (India)	Ward Leonard drive	20-100
PEC (Italy)	-	15-100
JOYO (Japan)	static scherbius system	10-100*
DFR (UK)	voltage control	-
BOR-60 (Russian Federation)	Ward Leonard drive	20-100
EBR-II (USA)	variable frequency power supply	-
Fermi (USA)	constant speed	-
FFTF (USA)	-	50-100
BR-10 (Russian Federation)	variable voltage	0-100
CEFR (China)	variable frequency power supply	15-100

Demonstration or Prototype Fast Reactors

Phénix (France)	variable speed alternator	15-100
SNR-300 (Germany)	revolution regulated	-
PFBR (India)	variable frequency power supply	15-100
MONJU (Japan)	fluid coupled MG set	40-100
PFR (UK)	fluid coupling	20-100
CRBRP (USA)	variable frequency power supply	-
BN-350 (Kazakhstan)	two fixed speeds	25 and 100
BN-600 (Russian Federation)	variable frequency power supply	25-100
ALMR (USA)	variable frequency power supply	-
KALIMER-150 (Republic of Korea)	to be determined	-
SVBR-75/100 (Russian Federation)	one fixed speed	-
BREST-OD-300 (Russian Federation)	variable frequency power supply	30-100

* 30-100 in MK-I, II

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Reactors

Plant	Main pumps	
	Principle of speed control	Operating range of speed control (% nominal flow)
Super-Phénix 1 (France)	variable speed alternator	15-100
Super-Phénix 2 (France)	-	-
SNR 2 (Germany)	-	-
DFBR (Japan)	variable frequency power supply	30-100
CDFR (UK)	fluid coupling	-
BN-1600 (Russian Federation)	to be determined	25-100
BN-800 (Russian Federation)	variable frequency power supply	25-100
EFR	variable frequency power supply	25-100
ALMR (USA)	variable frequency power supply	-
SVBR-75/100 (Russian Federation)	one fixed speed	-
BN-1800 (Russian Federation)	variable frequency power supply	25-100
BREST-1200 (Russian Federation)	variable frequency power supply	30-100
JSFR-1500 (Japan)	variable frequency power supply	15-100

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps	
	Materials of construction	
	Shaft	Hard facing alloy used in hydrostatic bearing
Rapsodie (France)	-	colmonoy
KNK-II (Germany)	-	-
FBTR (India)	921Cr/2Ni/2.7W	colmonoy
PEC (Italy)	Z15CNW22-12 (Norm. AFNOR)	stellite-12* (stellite-6**)
JOYO (Japan)	SCS13	stellite and 304
DFR (UK)	-	18/8/1
BOR-60 (Russian Federation)	SS	stellite
EBR-II (USA)	304	colmonoy
Fermi (USA)	304	colmonoy
FFTF (USA)	304	stellite-6
BR-10 (Russian Federation)	EM pumps	
CEFR (China)	304	stellite

Demonstration or Prototype Fast Reactors

Phénix (France)	-	colmonoy
SNR-300 (Germany)	-	-
PFBR (India)	304 LN	colmonoy
MONJU (Japan)	304	-
PFR (UK)	316	stellite
CRBRP (USA)	316	stellite
BN-350 (Kazakhstan)	SS	not applicable
BN-600 (Russian Federation)	SS	stellite
ALMR (USA)	EM pumps	
KALIMER-150 (Republic of Korea)	to be determined	
SVBR-75/100 (Russian Federation)	special steel	
BREST-OD-300 (Russian Federation)	Cr16Ni10	SiC

* rotating part
** fixed part

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Reactors

Plant	Main pumps	
	Materials of construction	
	Shaft	Hard facing alloy used in hydrostatic bearing
Super-Phénix 1 (France)	Cr 22 ni 12	colmonoy
Super-Phénix 2 (France)	-	-
SNR 2 (Germany)	-	-
DFBR (Japan)	-	-
CDFR (UK)	316	stellite
BN-1600 (Russian Federation)	SS	stellite
BN-800 (Russian Federation)	SS	stellite
EFR	-	stellite or colmonoy
ALMR (USA)	EM pumps	
SVBR-75/100 (Russian Federation)	special steel	
BN-1800 (Russian Federation)	to be determined	
BREST-1200 (Russian Federation)	Cr16Ni10	to be determined
JSFR-1500 (Japan)	12Cr-Steel	12Cr-Steel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Experimental Fast Reactors

Plant	Main pumps	
	Materials of construction	
	Impeller	Diffuser
Rapsodie (France)	316	316
KNK-II (Germany)	-	-
FBTR (India)	316	316
PEC (Italy)	Z6CND 19-10 (CF 814) (Norm. AFNOR)	same as impeller
JOYO (Japan)	SCS13	SCS13
DFR (UK)	-	-
BOR-60 (Russian Federation)	SS	SS
EBR-II (USA)	304	304
Fermi (USA)	304	304
FFTF (USA)	304	304
BR-10 (Russian Federation)	-	-
CEFR (China)	316	316

Demonstration or Prototype Fast Reactors

Phénix (France)	316	316
SNR-300 (Germany)	-	-
PFBR (India)	CF 3	CF 3
MONJU (Japan)	304	304
PFR (UK)	316	316
CRBRP (USA)	316	316
BN-350 (Kazakhstan)	SS	SS
BN-600 (Russian Federation)	SS	SS
ALMR (USA)	-	
KALIMER-150 (Republic of Korea)	to be determined	
SVBR-75/100 (Russian Federation)	special steel	
BREST-OD-300 (Russian Federation)	Cr16Ni10	Cr16Ni10

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.2. Main pumps

Commercial Size Reactors

Plant	Main pumps	
	Materials of construction	
	Impeller	Diffuser
Super-Phénix 1 (France)	Cr 22 Ni 10 Mn Si	
Super-Phénix 2 (France)	-	-
SNR 2 (Germany)	-	-
DFBR (Japan)	304	304
CDFR (UK)	316	316
BN-1600 (Russian Federation)	SS	SS
BN-800 (Russian Federation)	SS	SS
EFR	-	-
ALMR (USA)	Cr 22 Ni 10 Mn Si	
SVBR-75/100 (Russian Federation)	special steel	
BN-1800 (Russian Federation)	to be determined	
BREST-1200 (Russian Federation)	Cr16Ni10	Cr16Ni10
JSFR-1500 (Japan)	12Cr-Stee	12Cr-Steel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)
	Configuration of IHX - all designs are shell and straight tube, counterflow, with the primary coolant on the shell side, except where stated
Rapsodie (France)	shell and tubes, interm. coolant ins. tubes
KNK-II (Germany)	cross-counter-flow heat exchanger
FBTR (India)	shell and tubes, counter flow, primary coolant on shell side
PEC (Italy)	straight tube, counter flow, primary coolant on shell side, removable tube bundle
JOYO (Japan)	straight tube, counter flow, primart coolant on shell side, removable tube bundle
DFR (UK)	concentric tubes
BOR-60 (Russian Federation)	shell and straight tubes with floating head
EBR-II (USA)	straight tube counter flow
Fermi (USA)	shell and straight tube counter flow
FFTF (USA)	shell and straight tube counter flow
BR-10 (Russian Federation)	shell and straight tube flow
CEFR (China)	shell and tubes, with primary coolant in shell

Demonstration or Prototype Fast Reactors

Phénix (France)	shell and tubes with primary coolant in shell
SNR-300 (Germany)	straight tube with floating lower head
PFBR (India)	shell and tube, straight tubes, primary coolant on shell side
MONJU (Japan)	straight tube, counter flow, primary coolant on shell side
PFR (UK)	shell and tube, straight tubes, primary coolant in tubes
CRBRP (USA)	shell and tube, vertical, counter flow
BN-350 (Kazakhstan)	2 shells each containing 3 tube bundles, per loop
BN-600 (Russian Federation)	shell and tube, with primary coolant in shell
ALMR (USA)	shell and tube, with primary coolant in shell; kidney shaped
KALIMER-150 (Republic of Korea)	shell and tube, with primary coolant in shell
SVBR-75/100 (Russian Federation)	none
BREST-OD-300 (Russian Federation)	none

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)
	Configuration of IHX - all designs are shell and straight tube, counterflow, with the primary coolant on the shell side, except where stated
Super-Phénix 1 (France)	shell and tubes with primary coolant in shell
Super-Phénix 2 (France)	shell and tubes with primary coolant in shell
SNR 2 (Germany)	straight tube, primary coolant on shell side removable bundle
DFBR (Japan)	straight tube,counter flow,withprimary coolant in tubes
CDFR (UK)	shell and tube, with primary coolant in tubes
BN-1600 (Russian Federation)	shell and tube, with primary coolant in shell
BN-800 (Russian Federation)	shell and tube, with primary coolant in shell
EFR	shell and tube, with primary coolant in shell
ALMR (USA)	and tube, with primary coolant in shell; kidney shaped shell
SVBR-75/100 (Russian Federation)	none
BN-1800 (Russian Federation)	shell and tube, with primary coolant in shell
BREST-1200 (Russian Federation)	none
JSFR-1500 (Japan)	straight tube, counter flow, prim. cool. in tubes

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)		
	Coolant temperature (°C)		
	No. of units per primary loop	Primary inlet	Primary outlet
Rapsodie (France)	1	510	404
KNK-II (Germany)	2	525	360
FBTR (India)	1	380	515
PEC (Italy)	1 (1*)	545 (600 Max*)	400 (450 Max*)
JOYO (Japan)	1	500	350 (370 in MK-I, II)
DFR (UK)	1	350	200
BOR-60 (Russian Federation)	1	600	360
EBR-II (USA)	1	473	371
Fermi (USA)	1	427	288
FFTF (USA)	1	503	360
BR-10 (Russian Federation)	1	470	350
CEFR (China)	2	516	353

Demonstration or Prototype Fast Reactors

Phénix (France)	2	560	395
SNR-300 (Germany)	3	546	377
PFBR (India)	2	544	394
MONJU (Japan)	1	529	397
PFR (UK)	2	560	399
CRBRP (USA)	1	535	388
BN-350 (Kazakhstan)	2	430	280
BN-600 (Russian Federation)	2	535	365
ALMR (USA)	1	478	358
KALIMER-150 (Republic of Korea)	4	529.8	385
SVBR-75/100 (Russian Federation)	none		
BREST-OD-300 (Russian Federation)	none		

* test channel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)		
		Coolant temperature (°C)	
	No. of units per primary loop	Primary inlet	Primary outlet
Super-Phénix 1 (France)	2	542	392
Super-Phénix 2 (France)	2	544	395
SNR 2 (Germany)	2	-	-
DFBR (Japan)	1	550	395
CDFR (UK)	2	539	368
BN-1600 (Russian Federation)	2	550	395
BN-800 (Russian Federation)	2	547	354
EFR	2	545	395
ALMR (USA)	1	478	358
SVBR-75/100 (Russian Federation)	none		
BN-1800 (Russian Federation)	2	575	410
BREST-1200 (Russian Federation)	none		
JSFR-1500 (Japan)	1	550	395

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)	
	Coolant temperature (°C)	
	Secondary inlet	Secondary outlet
Rapsodie (France)	358	498
KNK-II (Germany)	322	504
FBTR (India)	284	510
PEC (Italy)	350 (435 Max*)	495 (585 Max*)
JOYO (Japan)	300 (340 in MK-I, II)	470
DFR (UK)	195	345
BOR-60 (Russian Federation)	320	565
EBR-II (USA)	307	465
Fermi (USA)	269	408
FFTF (USA)	316	459
BR-10 (Russian Federation)	270	380
CEFR (China)	310	495

Demonstration or Prototype Fast Reactors

Phénix (France)	350	540
SNR-300 (Germany)	335	520
PFBR (India)	355	525
MONJU (Japan)	325	505
PFR (UK)	370	540
CRBRP (USA)	344	502
BN-350 (Kazakhstan)	273	453
BN-600 (Russian Federation)	315	510
ALMR (USA)	325	477
KALIMER-150 (Republic of Korea)	339.7	511
SVBR-75/100 (Russian Federation)	none	
BREST-OD-300 (Russian Federation)	none	

* test channel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)	
	Coolant temperature (°C)	
	Secondary inlet	Secondary outlet
Super-Phénix 1 (France)	345	525
Super-Phénix 2 (France)	345	525
SNR 2 (Germany)	-	-
DFBR (Japan)	335	520
CDFR (UK)	335	510
BN-1600 (Russian Federation)	345	515
BN-800 (Russian Federation)	309	505
EFR	340	525
ALMR (USA)	325	477
SVBR-75/100 (Russian Federation)	none	
BN-1800 (Russian Federation)	370	540
BREST-1200 (Russian Federation)	none	
JSFR-1500 (Japan)	335	520

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)		
	Heat transfer capacity (MW per IHX)	Heat transfer area (m^2) (based on tube O.D, per IHX)	No. of tubes per IHX
Rapsodie (France)	18.6	92.0	888
KNK-II (Germany)	29	420	112
FBTR (India)	25 max	86.5	888
PEC (Italy)	58 (3*)	150 (9.7*)	1185 (183*)
JOYO (Japan)	70 (50 in MK- I, II)	363 (356, 352**)	2088 (1812**)
DFR (UK)	2.5	35	1
BOR-60 (Russian Federation)	30	215	1158
EBR-II (USA)	62	455	3248
Fermi (USA)	66.7	630	1860
FFTF (USA)	133	440	1540
BR-10 (Russian Federation)	4	9.5	85
CEFR (China)	16.4	112.1	540

Demonstration or Prototype Fast Reactors

Phénix (France)	94	450	2279
SNR-300 (Germany)	85	399	846
PFBR (India)	314.7	1612	3600
MONJU (Japan)	238		3200
PFR (UK)	100	239	1808
CRBRP (USA)	325	468	2850
BN-350 (Kazakhstan)	75	558	1029
BN-600 (Russian Federation)	245	590	4974
ALMR (USA)	424	2000	5519
KALIMER-150 (Republic of Korea)	98.75	407	1702
SVBR-75/100 (Russian Federation)	none		
BREST-OD-300 (Russian Federation)	none		

* test channel

** in MK- I, II, respectively

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)		
	Heat transfer capacity (MW per IHX)	Heat transfer area (m^2) (based on tube O.D, per IHX)	No. of tubes per IHX
Super-Phénix 1 (France)	375	1550	5380
Super-Phénix 2 (France)	450	-	-
SNR 2 (Germany)	-	-	-
DFBR (Japan)	534	1760	4392
CDFR (UK)	475	2718	-
BN-1600 (Russian Federation)	642	2340	6210
BN-800 (Russian Federation)	350	1657	4956
EFR	600	2037	5022
ALMR (USA)	424	2000	5519
SVBR-75/100 (Russian Federation)	none		
BN-1800 (Russian Federation)	667	2447	5226
BREST-1200 (Russian Federation)	none		
JSFR-1500 (Japan)	1765	4405	9200

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)				
	Dimension, shell (mm)		Dimension, tube (mm)		
	Outer diameter	Thickness	Outer diameter	Thickness	Length
Rapsodie (France)	700	8	14	1	2360
KNK-II (Germany)	1750	-	30	2	-
FBTR (India)	900	8	14	1	3450
PEC (Italy)	874 (350*)	6 (6*)	14 (14*)	1 (1*)	2865 (1200*)
JOYO (Japan)	1840 (1800)**	19 (18)	19 (22.2)	1.0 (1.2)	2930 (4130)
DFR (UK)	165	3.6	100	1.6	10700
BOR-60 (Russian Federation)	1200	20	20	2	3000
EBR-II (USA)	1820	-	16	1.24	3120
Fermi (USA)	1450	-	22.2	1.24	4660
FFTF (USA)	1990	30.2	22	1.2	6050
BR-10 (Russian Federation)	338	14	22	2.0	1590
CEFR (China)	980	25/10	16	1.4	3280

Demonstration or Prototype Fast Reactors

Phénix (France)	1210	-	14	1	5300
SNR-300 (Germany)	1350	-	21	1.4	7150
PFBR (India)	1900/1850	16.5	19	0.8	8050
MONJU (Japan)	3000	30	21.7	1.2	-
PFR (UK)	1441	12	19	1	4426
CRBRP (USA)	2670	41.3	22.2	1.14	7876
BN-350(Kazakhstan)	200x3000***	24	28	2	7000
BN-600 (Russian Federation)	2070	15	16	1.4	6360
ALMR (USA)	1073x4991****	19	15.9	0.89	7263
KALIMER-150 (Republic of Korea)	1046.5	20	12.7	0.8	6000
SVBR-75/100 (Russian Federation)	none				
BREST-OD-300 (Russian Federation)	none				

* test channel
** in MK-I , II, respectively
*** rectangular cross-section
**** kidney shaped cross-section

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)				
	Dimension, shell (mm)		Dimension, tube (mm)		
	Outer diameter	Thickness	Outer diameter	Thickness	Length
Super- Phénix 1 (France)	1830	8	14	1	6540
Super- Phénix 2 (France)	1940	-	-	-	-
SNR 2 (Germany)	-	-	-	-	-
DFBR (Japan)	2850		25.4	1.0	5400
CDFR (UK)	2500	20	25	1.0	8400
BN-1600 (Russian Federation)	2488	16	16	1.0	7455
BN-800 (Russian Federation)	2020	39	16	1.4	6615
EFR	2302	8	17.1	0.8	7550
ALMR (USA)	1073x4991****	19	15.9	0.89	7263
SVBR-75/100 (Russian Federation)	none				
BN-1800 (Russian Federation)	2450	25	16	1.0	9314
BREST-1200 (Russian Federation)	none				
JSFR-1500 (Japan)	5300	25	25.4	1.1	6000

**** kidney shaped cross-section

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Experimental Fast Reactors

Plant	Intermediate heat exchangers (IHX)	
	Material	
	Shell	Tube
Rapsodie (France)	316	316
KNK-II (Germany)	1.6770	1.6770
FBTR (India)	316	316
PEC (Italy)	316 (316*)	316 (316*)
JOYO (Japan)	316FR (304)**	316FR (304)**
DFR (UK)	18/8/1	18/8/1
BOR-60 (Russian Federation)	Cr 18 Ni 9	Cr 18 Ni 9
EBR-II (USA)	304	304
Fermi (USA)	304	304
FFTF (USA)	304	304
BR-10 (Russian Federation)	Cr 18 Ni 9 Ti	Cr 18 Ni 9 Ti
CFER (China)	316	316

Demonstration or Prototype Fast Reactors

Phénix (France)	316	316
SNR-300 (Germany)	1.4948	1.4948
PFBR (India)	316 LN	316 LN
MONJU (Japan)	304	304
PFR (UK)	316 (BS 1501)	316 (BS 3605)
CRBRP (USA)	304 and 316	TP 304H
BN-350 (Kazakhstan)	Cr 18 Ni 9	Cr 18 Ni 9
BN-600 (Russian Federation)	Cr 18 Ni 9	Cr 18 Ni 9
ALMR (USA)	304	304
KALIMER-150 (Republic of Korea)	304	304
SVBR-75/100 (Russian Federation)	none	
BREST-OD-300 (Russian Federation)	none	

* test channel
** in MK-I, II

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.3. Intermediate heat exchangers (IHX)

Commercial Size Reactors

Plant	Intermediate heat exchangers (IHX)	
	Material	
	Shell	Tube
Super-Phénix 1 (France)	Cr 18 Ni 12 Mo 2.5 Mn 1.8 Si	-
Super-Phénix 2 (France)	316	316
SNR 2 (Germany)	-	-
DFBR (Japan)	316 FR	316 FR
CDFR (UK)	316	316
BN-1600 (Russian Federation)	Cr 18 Ni 9	Cr 18 Ni 9
BN-800 (Russian Federation)	Cr 16 Ni 11 M 3	Cr 18 Ni 9 M 3
EFR	-	-
ALMR (USA)	304	304
SVBR-75/100 (Russian Federation)	none	
BN-1800 (Russian Federation)	Cr 16 Ni 11 M 3	Cr 18 Ni 9 M 3
BREST-1200 (Russian Federation)	none	
JSFR-1500 (Japan)	12Cr-Steel	12Cr-Steel

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators
	Configuration and type of steam cycle
Rapsodie (France)	no steam generator
KNK-II (Germany)	once-through evaporator, twin tubes
FBTR (India)	once through; triple S shaped tubes
PEC (Italy)	no steam generator
JOYO (Japan)	no steam generator
DFR (UK)	parallel tubes in copper heat transfer block
BOR-60 (Russian Federation)	*
EBR-II (USA)	once through; straight double wall tubes
Fermi (USA)	once through; cross and counter flow; helical coil helical coil
FFTF (USA)	no steam generators
BR-10 (Russian Federation)	no steam generator
CEFR (China)	once through; straight tubes, evaporator and superheater

Demonstration or Prototype Fast Reactors

Phénix (France)	once-through, vertical bank of large S-shaped tubes, each containing small pipes for water
SNR-300 (Germany)	once-through evaporator and separate superheater, tubes straight in 2 loops, helical in 3rd
PFBR (India)	once-through, straight tubes with evaporator and superheater in one unit
MONJU (Japan)	once-through evaporator and separate superheater; helical coiled; intermediate coolant on shell side
PFR (UK)	forced recirculation evaporator and drum separate superheater; separate reheater
CRBRP (USA)	forced recirculation evaporator modules feed one steam drum, separate superheater modules
BN-350 (Kazakhstan)	shell and tubes, Fild's tubes in evaporator, U-tubes in superheater**
BN-600 (Russian Federation)	shell and straight tubes, module type
ALMR (USA)	once-through helical coil
KALIMER-150 (Republic of Korea)	to be determined, evaporator and superheater in one unit
SVBR-75/100 (Russian Federation)	natural recirculation, Fild's tubes, evaporator with steam drum
BREST-OD-300 (Russian Federation)	once-through, helical coil evaporator and superheater in one unit

* five different type once through SG's were tested including those of Czech manufacture

** Czech SG's were in operation in two loops

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators
	Configuration and type of steam cycle
Super-Phénix 1 (France)	once-through evaporator and superheater with helical tubes
Super-Phénix 2 (France)	once-through evaporator and superheater with helical tubes
SNR 2 (Germany)	once-through, straight or coiled tube, intermediate coolant on shell side
DFBR (Japan)	once-through helical tubes
CDFR (UK)	once-through 'J' tubes
BN-1600 (Russian Federation)	not decided finally
BN-800 (Russian Federation)	shell-and straight tubes, module type
EFR	once-through, straight tubes with bellows on shell
ALMR (USA)	once-through helical coil
SVBR-75/100 (Russian Federation)	natural recirculation, Fild's tubes, evaporator with steam drum
BN-1800 (Russian Federation)	once-through, vessel-type (evaporator and superheater in one unit)
BREST-1200 (Russian Federation)	once-through, helical coil evaporator and superheater in one unit
JSFR-1500 (Japan)	once-through, double-wall straight tubes

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators		
	No. of evaporators per secondary loop	No. of superheaters per secondary loop	No. of reheaters per secondary loop
Rapsodie (France)	no steam generator		
KNK-II (Germany)	1*	-	0
FBTR (India)	2*	-	0
PEC (Italy)	no steam generator		
JOYO (Japan)	no steam generator		
DFR (UK)	12	12	0
BOR-60 (Russian Federation)	1	1	0
EBR-II (USA)	8	2	0
Fermi (USA)	1	1	1
FFTF (USA)	no steam generator		
BR-10 (Russian Federation)	no steam generator		
CEFR (China)	1	1	0

Demonstration or Prototype Fast Reactors

Phénix (France)	12	12	12
SNR-300 (Germany)	3	3	1 (steam heated)
PFBR (India)	4*	-	-
MONJU (Japan)	1	1	0
PFR (UK)	1	1	1
CRBRP (USA)	2	1	0
BN-350 (Kazakhstan)	2	2	0
BN-600 (Russian Federation)	8	8	8
ALMR (USA)	1	0	0
KALIMER-150 (Republic of Korea)	1	-	to be determined
SVBR-75/100 (Russian Federation)	2 (6 modules)	-	
BREST-OD-300 (Russian Federation)	1	-	0

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators		
	No. of evaporators per secondary loop	No. of superheaters per secondary loop	No. of reheaters per secondary loop
Super-Phénix 1 (France)	1*	-	0
Super-Phénix 2 (France)	1	1	0
SNR 2 (Germany)	2-4	2-4	0
DFBR (Japan)	1*	-	0
CDFR (UK)	2	2	0
BN-1600 (Russian Federation)	2*	-	0
BN-800 (Russian Federation)	10	10	0
EFR	1*	-	0
ALMR (USA)	1*	-	0
SVBR-75/100 (Russian Federation)	2 (6 modules)	-	-
BN-1800 (Russian Federation)	1*	-	0
BREST-1200 (Russian Federation)	1*	-	0
JSFR-1500 (Japan)	1*	-	0

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

	Steam generators					
	Coolant temperature (°C)					
	Evaporator		Superheater		Reheater	
Plant	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Rapsodie (France)	no steam generator					
KNK-II (Germany)	*	322	504	*	-	-
FBTR (India)	*	284	510	-	-	-
PEC (Italy)	no steam generator					
JOYO (Japan)	no steam generator					
DFR (UK)	295	215	325	295	-	-
BOR-60 (Russian Federation)	*	300	450	*	-	-
EBR-II (USA)	430	304	465	430	-	-
Fermi (USA)	385	290	408	385	269	290
FFTF (USA)	no steam generator					
BR-10 (Russian Federation)	no steam generator					
CEFR (China)	463.3	310	495	463.3		

Demonstration or Prototype Fast Reactors

Phénix (France)	478	350	550	473	550	473
SNR-300 (Germany)	455	335	520	455		
PFBR (India)	*	355	525	*		
MONJU (Japan)	469	325	505	469		
PFR (UK)	480	370	540	470	540	500
CRBRP (USA)	452	344	502	465		
BN-350 (Kazakhstan)	391	260	417	319		
BN-600 (Russian Federation)	449	328	518	449	518	449
ALMR (USA)	*	326	477	*	-	-
KALIMER-150 (Republic of Korea)	*	339	511	*	-	-
SVBR-75/100 (Russian Federation)	435	268	no superheater		-	-
BREST-OD-300 (Russian Federation)	*	420	540	*	-	-

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

	Steam generators					
	Coolant temperature (°C)					
	Evaporator		Superheater		Reheater	
Plant	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Super-Phénix 1 (France)	*	345	525	*	-	-
Super-Phénix 2 (France)	*	345	525	*	-	-
SNR 2 (Germany)	-	-	-	-	-	-
DFBR (Japan)	*	335	520	*	-	-
CDFR (UK)	510	335	510	335	-	-
BN-1600 (Russian Federation)	*	345	515	*	-	-
BN-800 (Russian Federation)	451	309	505	451	-	-
EFR	*	340	525	*	-	-
ALMR (USA)	*	326	477	*	-	-
SVBR-75/100 (Russian Federation)	435	268	no superheater		-	-
BN-1800 (Russian Federation)	*	370	540	*	-	-
BREST-1200 (Russian Federation)	*	420	540	*	-	-
JSFR-1500 (Japan)	*	335	520	*	-	-

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

	Steam generators			
	Water (steam) temperature (°C)			
	Evaporator		Superheater	
Plant	Inlet	Outlet	Inlet	Outlet
Rapsodie (France)	no steam generator			
KNK-II (Germany)	239	*	*	485
FBTR (India)	200	*	*	480
PEC (Italy)	no steam generator			
JOYO (Japan)	no steam generator			
DFR (UK)	191	194	194	274
BOR-60 (Russian Federation)	200	298	298	440438
EBR-II (USA)	304	304	304	
Fermi (USA)	-	-	-	407
FFTF (USA)	no steam generator			
BR-10 (Russian Federation)	no steam generator			
CEFR (China)	190	370.3	370.3	480

Demonstration or Prototype Fast Reactors

Phénix (France)	249	380	380	516
SNR-300 (Germany)	253	360	355	500
PFBR (India)	235	493	*	*
MONJU (Japan)	240	369	367	487
PFR (UK)	310	330	330	515
CRBRP (USA)	287	331	331	482
BN-350 (Kazakhstan)	158	256	256	415
BN-600 (Russian Federation)	240	366	366	505
ALMR (USA)	215	*	*	454
KALIMER-150 (Republic of Korea)	230	*	*	483.2
SVBR-75/100 (Russian Federation)	225	260	no superheater	
BREST-OD-300 (Russian Federation)	355	*	*	525

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

	Steam generators			
	Water (steam) temperature (°C)			
	Evaporator		Superheater	
Plant	Inlet	Outlet	Inlet	Outlet
Super-Phénix 1 (France)	237	*	*	490
Super-Phénix 2 (France)	237	*	*	490
SNR 2 (Germany)	-	-	-	-
DFBR (Japan)	240	*	*	497
CDFR (UK)	196	-	-	490
BN-1600 (Russian Federation)	240	*	*	495
BN-800 (Russian Federation)	210	382	382	490
EFR	240	*	*	490
ALMR (USA)	215	*	*	454
SVBR-75/100 (Russian Federation)	277	307	no superheater	
BN-1800 (Russian Federation)	270	*	*	~ 530
BREST-1200 (Russian Federation)	355	*	*	525
JSFR-1500 (Japan)	240	*	*	497

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

	Steam generators			
	Water (steam) temperature, reheater (°C)		Pressure of steam at outlet (Mpa)	
Plant	Inlet	Outlet	Superheater	Reheater
Rapsodie (France)	no steam generator			
KNK-II (Germany)	-	-	-	
FBTR (India)	-	-	-	12.6
PEC (Italy)	no steam generator			
JOYO (Japan)	no steam generator			
DFR (UK)	-	-	-	1.3
BOR-60 (Russian Federation)	-		-	8.8
EBR-II (USA)	-	-	-	8.83
Fermi (USA)	171	-	-	4.1
FFTF (USA)	no steam generator			
BR-10 (Russian Federation)	no steam generator			
CEFR (China)	-	-	-	14

Demonstration or Prototype Fast Reactors

Phénix (France)	318	525	16.3	3.5
SNR-300 (Germany)	-	-	16.7	-
PFBR (India)	-	-	17.2	-
MONJU (Japan)	-	-	12.5	
PFR (UK)	325	525	13.5	3.18
CRBRP (USA)			10.69	-
BN-350 (Kazakhstan)	-		4.9	-
BN-600 (Russian Federation)	300	505	13.7	2.6
ALMR (USA)	-	-	15.5	-
KALIMER-150 (Republic of Korea)	no reheater		15.5	
SVBR-75/100 (Russian Federation)	no superheater, pressure outlet of evaporator 4.7			
BREST-OD-300 (Russian Federation)	-	-	26.0	-

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

	Steam generators			
	Water (steam) temperature, reheater (°C)		Pressure of steam at outlet (MPa)	
Plant	Inlet	Outlet	Superheater	Reheater
Super-Phénix 1 (France)	-	-	18.4	-
Super-Phénix 2 (France)	-	-	18.4	-
SNR 2 (Germany)	-	-	-	-
DFBR (Japan)	-	-	17.2	-
CDFR (UK)	-	-	17.4	-
BN-1600 (Russian Federation)	-	-	13.7	-
BN-800 (Russian Federation)	-	-	13.7	-
EFR	-	-	18.5	-
ALMR (USA)	-	-	15.5	-
SVBR-75/100 (Russian Federation)	no superheater, pressure outlet of evaporator 9.5			
BN-1800 (Russian Federation)	275	525	25	3.5
BREST-1200 (Russian Federation)	-	-	26	-
JSFR-1500 (Japan)	-	-	19.2	-

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

	Steam generators		
	Tube material		
Plant	Evaporator	Superheater	Reheater
Rapsodie (France)	no steam generator		
KNK-II (Germany)	1.6770	-	-
FBTR (India)	2.25 Cr-1 Mo stab	2.25 Cr -1 Mo stab	-
PEC (Italy)	no steam generator		
JOYO (Japan)	no steam generator		
DFR (UK)	18/8/1	18/8/1	-
BOR-60 (Russian Federation)	2.25 Cr 1 Mo	2.25 Cr1 Mo and SS	-
EBR-II (USA)	2.25 Cr -1 Mo	2.25 Cr -1 Mo	-
Fermi (USA)	2.25 Cr -1 Mo	2.25 Cr -1 Mo	2.25 Cr -1 Mo
FFTF (USA)	no steam generator		
BR-10 (Russian Federation)	no steam generator		
CEFR (China)	2.25 Cr -1 Mo	2.25 Cr -1 Mo	-

Demonstration or Prototype Fast Reactors

Phénix (France)	2.25 Cr -1 Mo stab.+unstab	321 H	321 H
SNR-300 (Germany)	1.6770, 2.25 Cr-l Mo Nb stab	2.25 Cr -1 Mo Nb stab	-
PFBR (India)	Modified 9 Cr 1 Mo, evaporator and superheater in one unit	-	-
MONJU (Japan)	2.25 Cr -1 Mo	austenitic	
PFR (UK)	2.25 Cr -1 Mo Nb stab	9 Cr-1 Mo	9 Cr-1 Mo
CRBRP (USA)	2.25 Cr -1 Mo	2.25 Cr -1 Mo	-
BN-350 (Kazakhstan)	2.25 Cr -1 Mo	2.25 Cr -1 Mo	-
BN-600 (Russian Federation)	2.25 Cr -1 Mo	Cr 18 Ni 9	Cr 18 Ni 9
ALMR (USA)	2.25 Cr -1 Mo, evaporator and superheater in one unit		-
KALIMER-150 (Republic of Korea)	2.25 Cr -1 Mo, evaporator and superheater in one unit		-
SVBR-75/100 (Russian Federation)	duplex tube, no superheater and reheater		
BREST-OD-300 (Russian Federation)	9Cr -1 Mo, evaporator and superheater in one unit		-

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

	Steam generators		
	Tube material		
Plant	Evaporator	Superheater	Reheater
Super- Phénix 1 (France)	Ni 33 Cr 21 Ti Al Mn	-	-
Super- Phénix 2 (France)	Incoloy 800	-	-
SNR 2 (Germany)	12 Cr or2.25 Cr	1Cr or 2.25 Cr	-
DFBR (Japan)	Mod. 9 Cr 1 Mo	-	-
CDFR (UK)	9 Cr 1 Mo	9Cr 1 Mo	-
BN-1600 (Russian Federation)	2.25 Cr 1 Mo	2.25 Cr 1 Mo	-
BN-800 (Russian Federation)	10Cr 2 Mo VNB	10Cr 2 Mo VNB	-
EFR	9 Cr 1 Mo VNB	9 Cr 1 Mo VNB	-
ALMR (USA)	2.25 Cr 1 Mo, evaporator and superheater in one unit		-
SVBR-75/100 (Russian Federation)	duplex tube, no superheater and reheater		
BN-1800 (Russian Federation)	21Cr 32Ni, evaporator and superheater in one unit		10Cr 2 Mo
BREST-1200 (Russian Federation)	9Cr 1 Mo, evaporator and superheater in one unit		-
JSFR-1500 (Japan)	12Cr-Steel, evaporator and superheater in one unit		-

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators			
	Evaporator tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per evaporator module (m^2)
Rapsodie (France)	no steam generator			
KNK-II (Germany)	25/30	2.9	1	4.79
FBTR (India)	33.7	4	7	67
PEC (Italy)	no steam generator			
JOYO (Japan)	no steam generator			
DFR (UK)	25	2	10	16
BOR-60 (Russian Federation)	variable for different SG's			
EBR-II (USA)	36.5	4.57	73	51.1
Fermi (USA)	15.9	1.07	1200	201
FFTF (USA)	no steam generator			
BR-10 (Russian Federation)	no steam generator			
CEFR (China)	16.0	2.5	128	97

Demonstration or Prototype Fast Reactors

Phénix (France)	28	4	7	3.8
SNR-300 (Germany)	17.2	2	211	220
PFBR (India)	17.2	2.3	547	667
MONJU (Japan)	31.8	3.8	150	-
PFR (UK)	25	2.3	498	-
CRBRP (USA)	15.9	2.77	739	517
BN-350 (Kazakhstan)	32	2	816	410
BN-600 (Russian Federation)	16	2.5	349	251
ALMR (USA)	31.8*	5.7*	611*	5954*
KALIMER-150 (Republic of Korea)	23	3.5	224	971
SVBR-75/100 (Russian Federation)	26	1.5	301	93.4
BREST-OD-300 (Russian Federation)	17	3	580	852

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators			
	Evaporator tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per evaporator module (m^2)
Super-Phénix 1 (France)	25*	2.6*	357*	2570**
Super-Phénix 2 (France)	25*	-	424*	3100*
SNR 2 (Germany)	-	-	-	-
DFBR (Japan)	31.8*	3.9*	361*	3300*
CDFR (UK)	18*	3.1*	1940*	415*
BN-1600 (Russian Federation)	to be determined			
BN-800 (Russian Federation)	16	2.5	349	295
EFR	16.4*	2.2*	1386*	1740*
ALMR (USA)	31.8*	5.7*	611*	5954*
SVBR-75/100 (Russian Federation)	26	1.5	301	93.4
BN-1800 (Russian Federation)	16	2.0	1921	-
BREST-1200 (Russian Federation)	to be determined			
JSFR-1500 (Japan)	16.0 / 19.0	1.1 / 1.5	7230	12500

* evaporator and superheater in one unit

** Each of the SPX-1 tubes was ~92 m long. There were seven welds per tube, so SPX-1 had about 10000 welds in comparison with ~4000 in Phénix. The flow tubes were butt welded by the TIG (tungsten inert-gas) process with welding metal

*** double wall tube; inner tube/outer tube

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators			
	Superheater tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per superheater module (m^2)
Rapsodie (France)	no steam generator			
KNK-II (Germany)	see previous table*			
FBTR (India)	see previous table*			
PEC (Italy)	no steam generator			
JOYO (Japan)	no steam generator			
DFR (UK)	18	1.5	10	3
BOR-60 (Russian Federation)	variable for different SG's			
EBR-II (USA)	36.5	4.57	73	51.1
Fermi (USA)	15.9	1.07		712
FFTF (USA)	no steam generator			
BR-10 (Russian Federation)	no steam generator			
CEFR (China)	16.0	2.5	95	42.1

Demonstration or Prototype Fast Reactors

Phénix (France)	31.8	3.6	7	208
SNR-300 (Germany)	17.2	2.9	211	167.2
PFBR (India)	see previous table*			
MONJU (Japan)	31.8	3.5	150	
PFR (UK)	21	3.05	264	
CRBRP (USA)	15.9	2.77	739	517
BN-350 (Kazakhstan)	16	2	805	227
BN-600 (Russian Federation)	16	2.5	239	146
ALMR (USA)	see previous table*			
KALIMER-150 (Republic of Korea)	see previous table*			
SVBR-75/100 (Russian Federation)	no superheater			
BREST-OD-300 (Russian Federation)	see previous table			

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators			
	Superheater tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per superheater module (m^2)
Super-Phénix 1 (France)	see previous table*			
Super-Phénix 2 (France)	see previous table*			
SNR 2 (Germany)	-			
DFBR (Japan)	see previous table*			
CDFR (UK)	see previous table*			
BN-1600 (Russian Federation)	see previous table*			
BN-800 (Russian Federation)	16	2.5	239	161
EFR	see previous table*			
ALMR (USA)	see previous table*			
SVBR-75/100 (Russian Federation)	no superheater			
BN-1800 (Russian Federation)	see previous table*			
BREST-1200 (Russian Federation)	to be determined			
JSFR-1500 (Japan)	see previous table*			

* evaporator and superheater in one unit

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators			
	Reheater tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per reheater module (m^2)
Rapsodie (France)	no steam generator			
KNK-II (Germany)	no reheater			
FBTR (India)	no sodium reheater			
PEC (Italy)	no steam generator			
JOYO (Japan)	no steam generator			
DFR (UK)	no reheater			
BOR-60 (Russian Federation)	no reheater			
EBR-II (USA)	no reheater			
Fermi (USA)	15.9	1.07	90	-
FFTF (USA)	no steam generator			
BR-10 (Russian Federation)	no steam generator			
CEFR (China)	no sodium reheater			

Demonstration or Prototype Fast Reactors

Phénix (France)	42.4	2	7	2.6
SNR-300 (Germany)	no sodium reheater			
PFBR (India)	no sodium reheater			
MONJU (Japan)	no sodium reheater			
PFR (UK)	23.9	1.77	216	-
CRBRP (USA)	no reheater			
BN-350 (Kazakhstan)	no reheater			
BN-600 (Russian Federation)	25	2.5	235	224
ALMR (USA)	no sodium reheater			
KALIMER-150 (Republic of Korea)	no sodium reheater			
SVBR-75/100 (Russian Federation)	no reheater			
BREST-OD-300 (Russian Federation)	no lead reheater			

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators			
	Reheater tubes			
	Outer diameter (mm)	Thickness (mm)	No. per module	Effective heat transfer area per reheater module (m^2)
Super-Phénix 1 (France)	no sodium reheater			
Super-Phénix 2 (France)	-			
SNR 2 (Germany)	-			
DFBR (Japan)	no sodium reheater			
CDFR (UK)	no sodium reheater			
BN-1600 (Russian Federation)	no sodium reheater			
BN-800 (Russian Federation)	no sodium reheater			
EFR	no sodium reheater			
SVBR-75/100 (Russian Federation)	no reheater			
BN-1800 (Russian Federation)	to be determined			
BREST-1200 (Russian Federation)	no lead reheater			
JSFR-1500 (Japan)	no sodium reheater			

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators		
	Thermal capacity per evaporator module, (MWt)	Thermal capacity per superheater module, (MWt)	Thermal capacity per reheater module (MWt)
Rapsodie (France)	no steam generators		
KNK-II (Germany)	-	-	-
FBTR (India)	12.5	-	-
PEC (Italy)	no steam generators		
JOYO (Japan)	no steam generators		
DFR (UK)	0.5	0.5	0.5
BOR-60 (Russian Federation)	evaporator and superheater in one unit		
EBR-II (USA)	5.9	7.4	-
Fermi (USA)	45	12	10
FFTF (USA)	no steam generators		
BR-10 (Russian Federation)	no steam generators		
CEFR (China)	27.6	5.6	

Demonstration or Prototype Fast Reactors

Phénix (France)	10	3.37	2.6
SNR-300 (Germany)	55.4	30.1	-
PFBR (India)	158	evaporator and superheater in one unit	
MONJU (Japan)	191	47	-
PFR (UK)	130	55	25
CRBRP (USA)	162.5	325	-
BN-350 (Kazakhstan)	57	18	9.1
BN-600 (Russian Federation)	40.6	10.5	-
ALMR (USA)	850	evaporator and superheater in one unit	
KALIMER-150 (Republic of Korea)	198.35	evaporator and superheater in one unit	
SVBR-75/100 (Russian Federation)	22.5	no superheater and reheater	
BREST-OD-300 (Russian Federation)	175	evaporator and superheater in one unit	

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators		
	Thermal capacity per evaporator module, (MWt)	Thermal capacity per superheater module, (MWt)	Thermal capacity per reheater module (MWt)
Super-Phénix 1 (France)	750**	-	-
Super-Phénix 2 (France)	-	-	-
SNR 2 (Germany)	-	-	-
DFBR (Japan)	534*	-	-
CDFR (UK)	-	-	-
BN-1600 (Russian Federation)	-	-	-
BN-800 (Russian Federation)	50.5	19.5	-
EFR	600*	-	-
ALMR (USA)	850*	-	-
SVBR-75/100(Russian Federation)	22.5	no superheater and reheater	
BN-1800 (Russian Federation)	536*	to be determined	
BREST-1200 (Russian Federation)	to be determined	no lead reheater	
JSFR-1500 (Japan)	1765*	-	-

* evaporator and superheater in one unit

** the outstanding success of it operation has undoubtedly been the demonstration of reliable operation of SGs with high self power

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators
	Principle of leak detection system(s) and type of detector in argon or coolant
Rapsodie (France)	no steam generator
KNK-II (Germany)	hydrogen measuring
FBTR (India)	hydrogen detector
PEC (Italy)	no steam generator
JOYO (Japan)	-
DFR (UK)	NaK drip tray
BOR-60 (Russian Federation)	hydrogen measuring, acoustic noise detection
EBR-II (USA)	hydrogen measuring
Fermi (USA)	hydrogen detection
FFTF (USA)	no steam generator
BR-10 (Russian Federation)	no steam generator
CEFR (China)	hydrogen measuring

Demonstration or Prototype Fast Reactors

Phénix (France)	hydrogen detection
SNR-300 (Germany)	hydrogen detection
PFBR (India)	diffusion of hydrogen through nickel tubes kept under high vacuum; measurement based on sputter ion pump current
MONJU (Japan)	hydrogen meter, cover gas pressure meter and rupture disk sensor
PFR (UK)	hydrogen measuring
CRBRP (USA)	hydrogen and oxygen detection
BN-350 (Kazakhstan)	hydrogen detection and measuring
BN-600 (Russian Federation)	hydrogen detection and measuring
ALMR (USA)	hydrogen measuring
KALIMER-150 (Republic of Korea)	hydrogen measuring, acoustic noise detection
SVBR-75/100 (Russian Federation)	humidity in gas: increase of pressure in gas and lead-bismuth coolant
BREST-OD-300 (Russian Federation)	humidity in gas: increase of pressure in gas and lead coolant

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators
	Principle of leak detection system(s) and type of detector in argon or coolant
Super-Phénix 1 (France)	hydrogen detection/Nickel membrane detector
Super-Phénix (France)	hydrogen detection
SNR 2 (Germany)	-
DFBR (Japan)	hydrogen measuring
CDFR (UK)	hydrogen measuring
BN-1600 (Russian Federation)	hydrogen detection and measuring
BN-800 (Russian Federation)	hydrogen detection and measuring
EFR	hydrogen measuring, acoustic leak detection
ALMR (USA)	hydrogen measuring
SVBR-75/100 (Russian Federation)	humidity in gas: increase of pressure in gas and lead-bismuth coolant
BN-1800 (Russian Federation)	hydrogen detection and measuring
BREST-1200 (Russian Federation)	humidity in gas: increase of pressure in gas and lead coolant
JSFR-1500 (Japan)	hydrogen measuring

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators Position of leak detection system and its capacity to locate a leak
Rapsodie (France)	no steam generator
KNK-I (Germany)	secondary circuit
FBTR (India)	sodium outlet
PEC (Italy)	no steam generator
JOYO (Japan)	no steam generator
DFR (UK)	drip trays in each cubicle
BOR-60 (Russian Federation)	sodium outlet
EBR-II (USA)	sodium outlet
Fermi (USA)	cover gas
FFTF (USA)	no steam generator
BR-10 (Rusisa)	no steam generator
CEFR (China)	sodium and cover gas, no leakage positioning

Demonstration or Prototype Fast Reactors

Phénix (France)	sodium and cover gas
SNR-300 (Germany)	secondary circuit
PFBR (India)	sodium outlet of each SG and common sodium outlet from SG
MONJU (Japan)	five hydrogen meters in each intermediate circuit
PFR (UK)	within each gas space and also under-sodium
CRBRP (USA)	evaporator and superheater outlets and vent lines
BN-350 (Kazakhstan)	on the outlet of the steam generator and in gas
BN-600 (Russian Federation)	on the outlet of each module of the steam generator and in gas
ALMR (USA)	sodium and cover gas
KALIMER-150 (Republic of Korea)	sodium and cover gas
SVBR-75/100 (Russian Federation)	steam condenser of the primary circuit gas system
BREST-OD-300 (Russian Federation)	on the outlet of each SG and in gas

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators Position of leak detection system and its capacity to locate a leak
Super-Phénix 1 (France)	on the sodium outlet and in cover gas
Super-Phénix 2 (France)	sodium and cover gas
SNR 2 (Germany)	not decided
DFBR (Japan)	not decided
CDFR (UK)	not decided
BN-1600 (Russian Federation)	on the outlet of each module of the steam generator and in gas
BN-800 (Russian Federation)	on the outlet of each module of the steam generator and in gas
EFR	hydrogen at sodium inlet and outlet; acoustic noise via waveguides and transducer on steam generator shell
ALMR (USA)	sodium and cover gas
SVBR-75/100 (Russian Federation)	steam condenser of the primary circuit gas system
BN-1800 (Russian Federation)	on the outlet of the steam generator and in gas
BREST-1200 (Russian Federation)	on the outlet of each SG and in gas
JSFR-1500 (Japan)	to be determined

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators	
	Minimum detectable leak rate of steam into sodium	Response time of leak detection system
Rapsodie (France)	no steam generator	
KNK-II (Germany)	-	-
FBTR (India)	0.05 ppm H_2 in sodium	a few minutes
PEC (Italy)	no steam generator	
JOYO (Japan)	no steam generator	
DFR (UK)	-	-
BOR-60 (Russian Federation)	0.03 ppm H_2 in sodium	2 min
EBR-II (USA)	0.032 (g/s leak rate)	40 s
Fermi (USA)	1 ppm	30 s
FFTF (USA)	no steam generator	
BR-10 (Russian Federation)	no steam generator	
CEFR (China)	0.02 ppm	20-45 s

Demonstration or Prototype Fast Reactors

Phénix (France)	0.001 ppm in sodium	a few minutes
SNR-300 (Germany)	-	-
PFBR (India)	40 mg/s	135 s
MONJU (Japan)	0.01	not finalized
PFR (UK)	0.1 g/s (under-sodium system)	72 s
CRBRP (USA)	H_2-0.006 ppm; O_2-0.024 ppm	30 s
BN-350 (Kazakhstan)	0.01ppm (10 ppm*)	2 min (5 min*)
BN-600 (Russian Federation)	0.01 ppm (10 ppm*)	2 min (5 min*)
ALMR (USA)	0.6 g/s	100s
KALIMER-150 (Republic of Korea)	to be determined	
SVBR-75/100 (Russian Federation)	1 kg/h	≤ 1 kg/h
BREST-OD-300 (Russian Federation)	6.25 kg/s	100 s

* in gas space

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators	
	Minimum detectable leak rate of steam into sodium	Response time of leak detection system
Super-Phénix 1 (France)	0.1 g/s	~ 4 min
Super-Phénix 2 (France)	-	-
SNR 2 (Germany)	-	-
DFBR (Japan)	to be determined	
CDFR (UK)	-	-
BN-1600 (Russian Federation)	0.01 ppm (10 ppm*)	1.5 min (3 min*)
BN-800 (Russian Federation)	0.01 ppm (10 ppm*)	25 s (3 min*)
EFR	0.1g/s (H_2); 1g/s (acoustic)	350s (H_2); 20/s (acoustic)
ALMR (USA)	0.6g/s	100 s
SVBR-75/100 (Russian Federation)	1 kg/h	≤ 1 kg/h
BN-1800 (Russian Federation)	0.01 ppm (10 ppm*)	25 s (3 min*)
BREST-1200 (Russian Federation)	6.25 kg/s	1000 s
JSFR-1500 (Japan)	0.1 g/s	1900 s

* in gas space

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Experimental Fast Reactors

Plant	Steam generators Main features of system for discharge of sodium/water reaction products
Rapsodie (France)	no steam generator
KNK-II (Germany)	rupture discs at inlet and outlet of steam generator
FBTR (India)	rupture discs-discharge header-collection tank-hydrogen stack
PEC (Italy)	no steam generator
JOYO (Japan)	no steam generator
DFR (UK)	-
BOR-60 (Russian Federation)	rupture disc-separator tank
EBR-II (USA)	rupture disc-collection tank
Fermi (USA)	rupture disc to centrifugal separator to vent
FFTF (USA)	no steam generator
BR-10 (Russian Federation)	no steam generator
CEFR (China)	rupture disc-discharge pipe-dump tank-hydrogen stack

Demonstration or Prototype Fast Reactors

Phénix (France)	rupture discs-discharge pipe-collection tank- hydrogen stack
SNR-300 (Germany)	rupture discs at inlet and outlet of steam generator
PFBR (India)	rupture of rupture disc leads reaction products to storage tank; from there, H_2 gas is vented through the cyclone separator and chimney to atmosphere
MONJU (Japan)	rupture discs at evaporator and superheater
PFR (UK)	bursting discs to dump tank gases to atmosphere via cyclone separator
CRBRP (USA)	rupture discs-separator tanks-flare stack
BN-350 (Kazakhstan)	rupture disc - separator tanks
BN-600 (Russian Federation)	rupture disc - separator tanks
ALMR (USA)	rupture disc-dicharge pipe-dump tank-hydrogen stack
KALIMER-150 (Republic of Korea)	rupture disc-dicharge pipe-dump tank-hydrogen stack
SVBR-75/100 (Russian Federation)	no coolant-water reaction products
BREST-OD-300 (Russian Federation)	no coolant-water reaction; the disposal of lead oxides is carried by hydrogen lancing

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.4. Steam generators

Commercial Size Reactors

Plant	Steam generators Main features of system for discharge of sodium/water reaction products
Super-Phénix 1 (France)	rupture disc-discharge pipe-dump tank-hydrogen stack
Super-Phénix 2 (France)	rupture disc-discharge pipe-dump tank-hydrogen stack
SNR 2 (Germany)	-
DFBR (Japan)	rupture disc-discharge pipe-dump tank-hydrogen stack
CDFR (UK)	as for PFR
BN-1600 (Russian Federation)	rupture disc-discharge pipe-dump tank-hydrogen stack
BN-800 (Russian Federation)	rupture disc-discharge pipe-dump tank-hydrogen stack
EFR	rupture disc-discharge pipe-dump tank-hydrogen stack
ALMR (USA)	rupture disc-discharge pipe-dump tank-hydrogen stack
SVBR-75/100 (Russian Federation)	no lead-bismuth-water reaction
BN-1800 (Russian Federation)	as for BN-800
BREST-1200 (Russian Federation)	no lead-water reaction; the disposal of lead oxides is carried by hydrogen lancing
JSFR-1500 (Japan)	rupture disc-discharge pipe-dump tank-hydrogen stack

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.5. Turbine generators

Experimental Fast Reactors

Plant	Turbine generators	
	Type	Noumber of turbine generators (total)
Rapsodie (France)	no turbine generators	
KNK-II (Germany)	condensing reheat turbine	1
FBTR (India)	condensing	1
PEC (Italy)	no turbine generators	
JOYO (Japan)	no turbine generators	
DFR (UK)	single cylinder	-
BOR-60 (Russian Federation)	condensing	1
EBR-II (USA)	simple single flow	1
Fermi (USA)	tandem compound single flow	1
FFTF (USA)	no turbine generators	
BR-10 (Russian Federation)	no turbine generators	
CEFR (China)	condensing high single flow	1

Demonstration or Prototype Fast Reactors

Phénix (France)	condensing	-
SNR-300 (Germany)	condensing	1
PFBR (India)	tandem compound, reaction with throttle governing-condensing type	1
MONJU (Japan)	tandem compound	1
PFR (UK)	300 MW tandem compound/reheat/condensing	1
CRBRP (USA)	tandem compound	1
BN-350 (Kazakhstan)	condensing and back-pressure	4*
BN-600 (Russian Federation)	condensing reheat	3
ALMR (USA)	tandem compound	1
KALIMER-150 (Republic of Korea)	not yet decided	1
SVBR-75/100 (Russian Federation)	condensing	1
BREST-OD-300 (Russian Federation)	condensing reheat	1

* used different units

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.5. Turbine generators

Commercial Size Reactors

Plant	Turbine generators	
	Type	No. of turbine generators (total)
Super-Phénix 1 (France)	condensing	2
Super-Phénix 2 (France)	condensing	1
SNR 2 (Germany)	condensing	1
DFBR (Japan)	tandem compound	
CDFR (UK)	tandem compound	2
BN-1600 (Russian Federation)	condensing	2
BN-800 (Russian Federation)	condensing	1
EFR	condensing	1
ALMR (USA)	tandem compound	3 (serving 6 reactors)
SVBR-75/100 (Russian Federation)	condensing	1
BN-1800 (Russian Federation)	condensing reheat	1
BREST-1200 (Russian Federation)	condensing reheat	1
JSFR-1500 (Japan)	tandem compound	1

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.5. Turbine generators

Experimental Fast Reactors

Plant	Turbine generators			
	Power (MW)		Speed (rev./min.)	Minimum condenser pressure (MPa)
	Total	Per generator		
Rapsodie (France)	no turbine generators			
KNK-II (Germany)	58	-	3000	-
FBTR (India)	16	-	3000	0.012
PEC (Italy)	no turbine generators			
JOYO (Japan)	no turbine generators			
DFR (UK)	15	15	3000	-
BOR-60 (Russian Federation)	12	12	3000	0.004
EBR-II (USA)	20	20	3600	0.005
Fermi (USA)	150	150	1800	0.01
FFTF (USA)	no turbine generators			
BR-10 (Russian Federation)	no turbine generators			
CEFR (China)	25	25	3000	0.01

Demonstration or Prototype Fast Reactors

Phénix (France)	270	-	3000	0.002
SNR-300 (Germany)	327	-	3000	0.0047
PFBR (India)	500	-	3000	0.01
MONJU (Japan)	280	280	3600	0.0096
PFR (UK)	250	250	3000	-
CRBRP (USA)	380	-	3600	0.0068
BN-350 (Kazakhstan)	150	50 and 100	3000	0.006
BN-600 (Russian Federation)	600	200	3000	0.004
ALMR (USA)	300	300	3000	0.01
KALIMER-150 (Republic of Korea)	162.2	162.2	not yet decided	-
SVBR-75/100 (Russian Federation)	75	75	3000	0.00626
BREST-OD-300 (Russian Federation)	330	300	3000	0.00343

7. MAIN COMPONENTS OF HEAT TRANSPORT SYSTEM (cont.)

7.5. Turbine generators

Commercial Size Reactors

Plant	Turbine generators			
	Power (MW)		Speed (rev./min.)	Minimum condenser pressure (MPa)
	Total	Per generator		
Super-Phénix 1 (France)	1240	620	3000	0.0058
Super-Phénix 2 (France)	1500	1500	1500	-
SNR 2 (Germany)	-	-	1500	-
DFBR (Japan)	660	660	-	-
CDFR (UK)	1320	660	3000	0.0044
BN-1600 (Russian Federation)	1600	800	3000	0.004
BN-800 (Russian Federation)	1080	1000	3000	0.004
EFR	1580	1580	1500	0.006
ALMR (USA)	600*	600*	3000	0.01
SVBR-75/100 (Russian Federation)	75	75	3000	0.00626
BN-1800 (Russian Federation)	not yet decided		3000	0.004
BREST-1200 (Russian Federation)	1200	1250	3000	not yet decided
JSFR-1500 (Japan)	1500	1500	1500	0.0096

* serving two reactors