11. REFUELLING

11.1. Refuelling methods

Experimental Fast Reactors

	Refuelling methods
Plant	Method used within primary vessel
Rapsodie (France)	2 RP and 2 VM
KNK-II (Germany)	-
FBTR (India)	2 VM and 2 RP
PEC (Italy)	under VH by PM in 1 RP
JOYO (Japan)	VM in 2 RP
DFR (UK)	VM in 2 RP
BOR-60 (Russian Federation)	VM in 2 RP
EBR-II (USA)	VM in 2 RP and transfer arm
Fermi (USA)	VM, fixed exit port, RP with offset mechanism
FFTF (USA)	3 VM each in 1 RP
BR-10 (Russian Federation)	2RP and 1 VM
CEFR (China)	VM in 2 RP, IVS

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Phénix (France)	fixed offset arm in 1 RP, IVS
SNR-300 (Germany)	VM in 3 RP
PFBR (India)	fixed offset arm in 2 RP, IVS
MONJU (Japan)	fixed offset arm in 1 RP
PFR (UK)	PM in 1 RP, IVS
CRBRP (USA)	VM in 3 RP
BN-350 (Kazakhstan)	VM in 2 RP, IVS
BN-600 (Russian Federation)	2 VM in 2 RP, IVS
ALMR (USA)	2 PM in 2 RP
KALIMER-150 (Republic of Korea)	PM, RP, IVS
SVBR-75/100 (Russian Federation)	VM
BREST-OD-300 (Russian Federation)	2RP+VM+rotating mechanism +horizontal transfer mechanism

RP - rotating plug
VM - Vertical mechanism (direct lift)
VH - vessel head
FM - fixed-arm mechanism
PM - pantograph mechanism
IVS - fuel store within primary vessel

11. REFUELLING (cont.)

11.1. Refuelling methods

Commercial Size Reactors

	Refuelling methods
Plant	Method used within primary vessel
Super-Phénix 1 (France)	2 VM in 2 RP
Super-Phénix 2 (France)	1 VM in 2 RP
SNR 2 (Germany)	under head to transfer position
DFBR (Japan)	VM and PM in 2 RP
CDFR (UK)	1 VM in 2 RP
BN-1600 (Russian Federation)	VM in 3 RP, IVS
BN-800 (Russian Federation)	VM in 3 RP, IVS
EFR	RP, VM, FM, IVS
ALMR (USA)	2 PM in 2 RP
SVBR-75/100 (Russian Federation)	VM
BN-1800 (Russian Federation)	VM in 3 RP, IVS
BREST-1200 (Russian Federation)	2RP,VM, to be defined
JSFR-1500 (Japan)	1 PM in 1 RP

RP - rotating plug
VM - Vertical mechanism (direct lift)
VH - vessel head
FM - fixed-arm mechanism
PM - pantograph mechanism
IVS - fuel store within primary vessel

11. REFUELLING (cont.)

11.1. Refuelling methods

Experimental Fast Reactors

Plant	Refuelling methods	
	Methods used to store spent fuel	Method used to handle fuel outside primary vessel
Rapsodie (France)	OSC	MF
KNK-II (Germany)	through FHP by TM to OPV	
FBTR (India)	by TM to OSC	
PEC (Italy)	through FHP by MC to transfer and external examination cells	
JOYO (Japan)	through port in outer rotating plug via MC on gantry	
DFR (UK)	mobile flask to OSC	
BOR-60 (Russian Federation)	OPV	MF
EBR-II (USA)	through FHP by cask car through airlock	
Fermi (USA)	through FHP by cask car through airlock	
FFTF (USA)	through 1 of 3 FHP by MC on gantry	
BR-10 (Russian Federation)	OSC	MF
CEFR (China)	ORB (54) for primary, OSC (943) for secondary	MF

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Phénix (France)	ORB (43) + OSC	TA
SNR-300 (Germany)	through FHP by MC on bridge crane	
PFBR (India)	ORB (156) + OSC (711) in DM water pool	TA
MONJU (Japan)	through TM to OPV by FHP to OSC	
PFR (UK)	through FHP by MC on overhead crane to OPV	
CRBRP (USA)	through port in outer plug via MC on gantry	FHP
BN-350 (Kazakhstan)	through elevator by TM to OPV	FHP
BN-600 (Russian Federation)	through elevator by TM to OPV	MF
BREST-OD-300 (Russian Federation)	storage in primary vessel+VM+TM	MF,VM
KALIMER-150 (Republic of Korea)	through FHP by MC to outside reactor bilding	MF, FHP
SVBR-75/100 (Russian Federation)**	OSC (55)	MF

MC - mobile cask
TM - transfer mechanism
FHP - fixed head port
ORB - storage in diagrid positions outside radial blanket
RS - storage in rotor or basket within primary vessel
OPV - storage outside primary vessel but inside secondary containment
OSC - storage outside secondary containment [Figure in parentheses, e.g., RS(20), indicates number of storage positions]
MF - mobile transfer flask
TA - transfer within an A-frame
FHP - transfer within a fixed head port

11. REFUELLING (cont.)

11.1. Refuelling methods

Commercial Size Reactors

Plant	Refuelling methods	
	Methods used to store spent fuel	Method used to handle fuel outside primary vessel
Super-Phénix 1 (France)	OSC (1344)	TA
Super-Phénix 2 (France)	OSC (1300)	TA
SNR 2 (Germany)	through FHP via fixed TM in inerted cells	
DFBR (Japan)		
CDFR (UK)	through fixed transfer lock to OPV	
BN-1600 (Russian Federation)	through elevator by TM to OPV	FHP
BN-800 (Russian Federation)	through elevator by TM to OPV	FHP
EFR	ORB (234)+(OPV (800)+OSC	TA
ALMR (USA)*	RS	MF
SVBR-75/100 (Russian Federation)	OSC (55)	MF
BN-1800 (Russian Federation)	through elevator by TM to OPV	FHP
BREST-1200 (Russian Federation)	storage in primary vessel+VM+TM	to be defined
JSFR-1500 (Japan)	through MC to OSC	MF

* the same methods used to store spent fuel for ALMR demo

MC - mobile cask
TM - transfer mechanism
FHP - fixed head port
ORB - storage in diagrid positions outside radial blanket
RS - storage in rotor or basket within primary vessel
OPV - storage outside primary vessel but inside secondary containment
OSC - storage outside secondary containment [Figure in parentheses, e.g., RS(20), indicates number of storage positions]
MF - mobile transfer flask
TA - transfer within an A-frame
FHP - transfer within a fixed head port

11. REFUELLING (cont.)

11.2. Cooling during refueling

Experimental Fast Reactors

Plant	Cooling during refueling
	Cooling method of fuel subassembly during handling in vessel
Rapsodie (France)	sodium immersion
KNK-II (Germany)	by argon
FBTR (India)	sodium immersion
PEC (Italy)	sodium immersion
JOYO (Japan)	sodium immersion
DFR (UK)	forced cooling system in charge machine
BOR-60 (Russian Federation)	sodium immersion
EBR-II (USA)	sodium immersion
Fermi (USA)	finned pots, sodium immersion
FFTF (USA)	sodium immersion
BR-10 (Russian Federation)	sodium immersion
CEFR (China)	sodium immersion

Demonstration or Prototype Fast Reactors

Phénix (France)	sodium immersion
SNR-300 (Germany)	not determined
PFBR (India)	sodium immersion
MONJU (Japan)	sodium immersion
PFR (UK)	sodium immersion
CRBRP (USA)	sodium immersion
BN-350 (Kazakhstan)	sodium immersion
BN-600 (Russian Federation)	sodium immersion
ALMR (USA)	sodium immersion
KALIMER-150 (Republic of Korea)	sodium immersion
SVBR-75/100 (Russian Federation)	lead-bismuth immersion, by argon
BREST-OD-300 (Russian Federation)	lead immersion, by argon

11. REFUELLING (cont.)

11.2. Cooling during refueling

Commercial Size Reactors

Plant	Cooling during refueling
	Cooling method of fuel subassembly during handling in vessel
Super-Phenix 1 (France)	sodium immersion
Super-Phenix 2 (France)	sodium immersion
SNR 2 (Germany)	not determined
DFBR (Japan)	sodium immersion
CDFR (UK)	sodium immersion
BN-1600 (Russian Federation)	sodium immersion
BN-800 (Russian Federation)	sodium immersion
EFR	sodium immersion
ALMR (USA)	sodium immersion
SVBR-75/100 (Russian Federation)	lead-bismuth immersion, by argon
BN-1800 (Russian Federation)	sodium immersion
BREST-1200 (Russian Federation)	lead immersion, by argon
JSFR-1500 (Japan)	sodium immersion

11. REFUELLING (cont.)

11.2. Cooling during refueling

Experimental Fast Reactors

Plant	Cooling during refueling
	Cooling method of fuel subassembly during handling outside the primary vessel
Rapsodie (France)	natural convection in argon
KNK-II (Germany)	by argon
FBTR (India)	no special provision
PEC (Italy)	sodium pots and forced ventilation through the subassembly and radiation to a cold wall cooled by air under forced convection
JOYO (Japan)	argon
DFR (UK)	forced cooling system in charge inactive
BOR-60 (Russian Federation)	by argon
EBR-II (USA)	by argon
Fermi (USA)	finned pots
FFTF (USA)	radiation to a cold wall cooled by air under forced convection
BR-10 (Russian Federation)	natural convection in argon
CEFR (China)	by argon if necessary

Demonstration or Prototype Fast Reactors

Phénix (France)	Na-filled bucket. Natural convection in bucket and argon cooling outside bucket
SNR-300 (Germany)	not determined
PFBR (India)	Na-filled pot under natural convection and subsequently forced convection in nitrogen
MONJU (Japan)	Na -filled pot
PFR (UK)	Na-filled bucket. Natural convection in bucket and argon cooling outside bucket
CRBRP (USA)	transfer in sodium-filled pot, heat transfer through argon to finned tube cooled by forced air
BN-350 (Kazakhstan)	by nitrogen
BN-600 (Russian Federation)	without forced cooling
ALMR (USA)	by helium within flask and naturally circulating air outside flask
KALIMER-150 (Republic of Korea)	gas cooled in flask and air cooled outside flask
SVBR-75/100 (Russian Federation)	air cooling
BREST-OD-300 (Russian Federation)	by argon

11. REFUELLING (cont.)

11.2. Cooling during refueling

Commercial Size Reactors

Plant	Cooling during refueling
	Cooling method of fuel subassembly during handling outside the primary vessel
Super-Phénix 1 (France)	Na-filled buckets under natural convection in argon gas
Super-Phénix 2 (France)	not determined
SNR 2 (Germany)	not determined
DFBR (Japan)	sodium filled pot in argon-filled flask with air- cooled wall
CDFR (UK)	convection in Na and forced cooling with argon
BN-1600 (Russian Federation)	without forced cooling
BN-800 (Russian Federation)	without forced cooling
EFR	Na-filled pot under natural and forced convection in nitrogen
ALMR (USA)	by helium within flask and naturally circulating air outside flask
SVBR-75/100 (Russian Federation)	air cooling
BN-1800 (Russian Federation)	thout forced cooling
BREST-1200 (Russian Federation)	by argon
JSFR-1500 (Japan)	argon

11. REFUELLING (cont.)

11.2. Cooling during refueling

Experimental Fast Reactors

Plant	Cooling during refueling
	Maximum allowable fuel pin cladding temperature during handling (°C)
Rapsodie (France)	650
KNK-II (Germany)	650
FBTR (India)	650
PEC (Italy)	450
JOYO (Japan)	470
DFR (UK)	-
BOR-60 (Russian Federation)	600
EBR-II (USA)	depends on type of fuel and necessity for rapid fuel handling for post irradiation examination or other reasons
Fermi (USA)	-
FFTF (USA)	538
BR-10 (Russian Federation)	600
CEFR (China)	700

Demonstration or Prototype Fast Reactors

Phénix (France)	700
SNR-300 (Germany)	not determined
PFBR (India)	650
MONJU (Japan)	-
PFR (UK)	630
CRBRP (USA)	675
BN-350 (Kazakhstan)	600
BN-600 (Russian Federation)	600
ALMR (USA)	675
KALIMER-150 (Republic of Korea)	not determined
SVBR-75/100 (Russian Federation)	600
BREST-OD-300 (Russian Federation)	450

11. REFUELLING (cont.)

11.2. Cooling during refueling

Commercial Size Reactors

Plant	Cooling during refueling
	Maximum allowable fuel pin cladding temperature during handling (°C)
Super-Phénix 1 (France)	650
Super-Phénix 2 (France)	700
SNR 2 (Germany)	not determined
DFBR (Japan)	700
CDFR (UK)	650
BN-1600 (Russian Federation)	600
BN-800 (Russian Federation)	600
EFR	650
ALMR (USA)	675
SVBR-75/100 (Russian Federation)	600
BN-1800 (Russian Federation)	650
BREST-1200 (Russian Federation)	to be determined
JSFR-1500 (Japan)	600 within 30 days, 630 within 24 hr

11. REFUELLING (cont.)

11.3. Method of identifying subassemblies and core components during handling operations

Experimental Fast Reactors

Plant	Method of identifying subassemblies and core components during handling operations
Rapsodie (France)	visual
KNK-II (Germany)	visual
FBTR (India)	visual
PEC (Italy)	visual with optical aids
JOYO (Japan)	1 TV (reactor vessel)
DFR (UK)	introscope through top shield
BOR-60 (Russian Federation)	visual with optical aids
EBR-II (USA)	visual with optical aids
Fermi (USA)	visual with optical aids
FFTF (USA)	in two shielded argon-filled hot cells
BR-10 (Russian Federation)	visual
CEFR (China)	conputer control and visual with optical aids if necessary

Demonstration or Prototype Fast Reactors

Phénix (France)	visual
SNR-300 (Germany)	vessel: outer inspection by TV
PFBR (India)	visual
MONJU (Japan)	visual with optical aids
PFR (UK)	remote viewing
CRBRP (USA)	visual with optical aids, dimensional measurement
BN-350 (Kazakhstan)	visual with optical aids
BN-600 (Russian Federation)	visual with optical aids
ALMR (USA)	visual with optical aids
KALIMER-150 (Republic of Korea)	not determined
SVBR-75/100 (Russian Federation)	mechanical positioning
BREST-OD-300 (Russian Federation)	visual with optical aids, identification bulges on tail of subassemblies

11. REFUELLING (cont.)

11.3. Method of identifying subassemblies and core components during handling operations

Commercial Size Reactors

Plant	Method of identifying subassemblies and core components during handling operations
Super-Phénix 1 (France)	visual
Super-Phénix 2 (France)	visual
SNR 2 (Germany)	
DFBR (Japan)	visual
CDFR (UK)	remote viewing
BN-1600 (Russian Federation)	visual with optical aids
BN-800 (Russian Federation)	visual with optical aids
EFR	visual with TV camera
ALMR (USA)	visual with optical aids
SVBR-75/100 (Russian Federation)	mechanical positioning
BN-1800 (Russian Federation)	visual with optical aids
BREST-1200 (Russian Federation)	visual with optical aids, identification bulges on tail of subassemblies
JSFR-1500 (Japan)	to be determined

11. REFUELLING (cont.)

11.4. Main method of removing coolant from subassemblies and core components

Experimental Fast Reactors

Plant	Main method of removing coolant from subassemblies and core components
Rapsodie (France)	nitrogen with steam and washing
KNK-II (Germany)	-
FBTR (India)	-
PEC (Italy)	-
JOYO (Japan)	argon with steam
DFR (UK)	-
BOR-60 (Russian Federation)	nitrogen with steam or alcoholic solution cleaning and washing
EBR-II (USA)	-
Fermi (USA)	-
FFTF (USA)	-
BR-10 (Russian Federation)	nitrogen with steam and washing
CEFR (China)	nitrogen with steam and washing

Demonstration or Prototype Fast Reactors

Phénix (France)	washing with CO_2 and H_2O
SNR-300 (Germany)	not determined
PFBR (India)	nitrogen with steam and washing
MONJU (Japan)	-
PFR (UK)	steam cleaning and washing
CRBRP (USA)	-
BN-350 (Kazakhstan)	argon with steam and washing
BN-600 (Russian Federation)	argon with steam and washing
ALMR (USA)	drip drying in helium atmosphere
KALIMER-150 (Republic of Korea)	to be determined
SVBR-75/100 (Russian Federation)	none
BREST-OD-300 (Russian Federation)	drip drying in argon atmosphere

11. REFUELLING (cont.)

11.4. Main method of removing coolant from subassemblies and core components

Commercial Size Reactors

Plant	Main method of removing coolant from subassemblies and core components
Super-Phénix 1 (France)	washing with CO_2 and H_2O
Super-Phénix 2 (France)	not determined
SNR 2 (Germany)	not determined
DFBR (Japan)	cleaning with high temperature argon
CDFR (UK)	not determined
BN-1600 (Russian Federation)	not determined
BN-800 (Russian Federation)	argon with steam and washing
EFR	washing with CO_2 and H_2O
ALMR (USA)	drip drying in helium atmosphere
SVBR-75/100 (Russian Federation)	none
BN-1800 (Russian Federation)	argon with steam and washing
BREST-1200 (Russian Federation)	drip drying in argon atmosphere
JSFR-1500 (Japan)	argon with steam