

## REFUELLING

- 11.1. Refuelling methods
- 11.1.1. Method used within primary vessel
  - RP - rotating plug
  - VM - vertical mechanism (direct lift)
  - VH - vessel head
  - FM - fixed-arm mechanism
  - PM - pantograph mechanism
  - IVS - fuel store within primary vessel

### Experimental Fast Reactors

Plant	11.1.1.
Rapsodie (France)	2 RP and 2 VM
KNK-II (Germany)	
FBTR (India)	2 VM and 2 RP
PEC (Italy)	under VH by PM 1 RP
JOYO (Japan)	VM in 2 RP
DFR (UK)	VM in 2 RP
BOR-60 (Russia)	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 (Russia)	2RP and 1 VM
CEFR (China)	VM in 2 RP, IVS

### Demonstration or Prototype Fast Reactors

Phénix (France)	fixed off-set arm in 1 RP, IVS
SNR-300 (Germany)	VM in 3 RP
PFBR (India)	VM in 2 RP
MONJU (Japan)	fixed off-set 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 (Russia)	2 VM in 2 RP, IVS
ALMR (USA)	2 PM in 2 RP

### Commercial Size Reactors

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 (Russia)	VM in 3 RP, IVS
BN-800 (Russia)	VM in 3 RP, IVS
EFR	RP, VM, FM, IVS
ALMR (USA)	2 PM in 2 RP

## REFUELLING

- 11.1. Refuelling methods
- 11.1.2. Methods used to store spent fuel
  - 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]
- 11.1.3. Method used to handle fuel outside primary vessel
  - MF - mobile transfer flask
  - TA - transfer within an A-frame
  - FHP - transfer within a fixed head port

### Experimental Fast Reactors

Plant	11.1.2.	11.1.3.
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 cell and external examination cells	
JOYO (Japan)	through port in outer rotating plug via MC on gantry	
DFR (UK)	mobile flask to OSC	
BOR-60 (Russia)	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 (Russia)	OSC	MF on crane
CEFR (China)	ORB (54) for primary, OSC (943) for secondary	MF
<b>Demonstration or Prototype Fast Reactors</b>		
Phénix (France)	ORB (43) + OSC	TA
SNR-300 (Germany)	through FHP by MC on bridge crane	
PFBR (India)	by TM to OPV	
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 (Russia)	through elevator by TM to OPV	MF
ALMR (USA)	FR	
<b>Commercial Size Reactors</b>		
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 (Russia)	through elevator by TM to OPV	FHP
BN-800 (Russia)	through elevator by TM to OPV	FHP
EFR	ORB (234)+(OPV (800))+OSC	TA
ALMR (USA)	FR	MF

## REFUELLING

- 11.2. Cooling during refueling
- 11.2.1. Cooling method of fuel subassembly during handling in vessel

### Experimental Fast Reactors

Plant	11.2.1.
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 (Russia)	sodium immersion
EBR-II (USA)	sodium immersion
Fermi (USA)	finned pots, sodium immersion
FFTF (USA)	sodium immersion
BR-10 (Russia)	sodium immersion
CEFR (China)	sodium immersion

### Demonstration or Prototype Fast Reactors

Phénix (France)	sodium immersion
SNR-300 (Germany)	
PFBR (India)	sodium immersion
MONJU (Japan)	sodium immersion
PFR (UK)	sodium immersion
CRBRP (USA)	sodium immersion
BN-350 (Kazakhstan)	sodium immersion
BN-600 (Russia)	sodium immersion
ALMR (USA)	sodium immersion

### Commercial Size Reactors

Super-Phénix 1 (France)	sodium immersion
Super-Phénix 2 (France)	sodium immersion
SNR 2 (Germany)	
DFBR (Japan)	sodium immersion
CDFR (UK)	sodium immersion
BN-1600 (Russia)	sodium immersion
BN-800 (Russia)	sodium immersion
EFR	sodium immersion
ALMR (USA)	sodium immersion

## REFUELLING

- 11.2. Cooling during refueling
- 11.2.2. Cooling method of fuel subassembly during handling outside the primary vessel

### Experimental Fast Reactors

Plant	11.2.2.
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 (Russia)	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 (Russia)	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)	
PFBR (India)	no special provision
MONJU (Japan)	sodium-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 (Russia)	without forced cooling
ALMR (USA)	by helium within flask and naturally circulating air outside flask

### Commercial Size Reactors

Super-Phénix 1 (France)	Na-filled buckets under natural convection in argon gas
Super-Phénix 2 (France)	
SNR 2 (Germany)	
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 (Russia)	without forced cooling
BN-800 (Russia)	without forced cooling
EFR	sodium-filled pot under natural and forced convection in nitrogen
ALMR (USA)	by helium within flask and naturally circulating air outside flask

## REFUELLING

- 11.2. Cooling during refueling  
11.2.3. Maximum allowable fuel pin cladding temperature during handling (°C)

### Experimental Fast Reactors

Plant	11.2.3.
Rapsodie (France)	650
KNK-II (Germany)	650
FBTR (India)	650
PEC (Italy)	450
JOYO (Japan)	470
DFR (UK)	
BOR-60 (Russia)	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 (Russia)	600
CEFR (China)	600

### Demonstration or Prototype Fast Reactors

Phénix (France)	700
SNR-300 (Germany)	
PFBR (India)	650
MONJU (Japan)	
PFR (UK)	630
CRBRP (USA)	675
BN-350 (Kazakhstan)	600
BN-600 (Russia)	600
ALMR (USA)	675

### Commercial Size Reactors

Super-Phénix 1 (France)	650
Super-Phénix 2 (France)	700
SNR 2 (Germany)	
DFBR (Japan)	700
CDFR (UK)	650
BN-1600 (Russia)	600
BN-800 (Russia)	600
EFR	650
ALMR (USA)	675

## REFUELLING

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

#### Experimental Fast Reactors

Plant	11.3.
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 (Russia)	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 (Russia)	visual
CEFR (China)	visual with optical aids

#### 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 (Russia)	visual with optical aids
ALMR (USA)	visual with optical aids

#### Commercial Size Reactors

Super-Phénix 1 (France)	visual
Super-Phénix 2 (France)	visual
SNR 2 (Germany)	
DFBR (Japan)	visual
CDFR (UK)	remote viewing
BN-1600 (Russia)	visual with optical aids
BN-800 (Russia)	visual with optical aids
EFR	visual with TV camera
ALMR (USA)	visual with optical aids

## REFUELLING

### 11.4. Main method of removing sodium from subassemblies and core components

#### Experimental Fast Reactors

Plant	11.4.
Rapsodie (France)	nitrogen with steam and washing
KNK-II (Germany)	
FBTR (India)	
PEC (Italy)	
JOYO (Japan)	argon with steam
DFR (UK)	
BOR-60 (Russia)	steam cleaning and washing
EBR-II (USA)	
Fermi (USA)	
FFTF (USA)	
BR-10 (Russia)	nitrogen with steam and washing
CEFR (China)	argon with steam and washing

#### Demonstration or Prototype Fast Reactors

Phénix (France)	washing with CO <sub>2</sub> and H <sub>2</sub> O
SNR-300 (Germany)	
PFBR (India)	
MONJU (Japan)	
PFR (UK)	steam cleaning and washing
CRBRP (USA)	
BN-350 (Kazakhstan)	argon with steam and washing
BN-600 (Russia)	argon with steam and washing
ALMR (USA)	drip drying in helium atmosphere

#### Commercial Size Reactors

Super-Phénix 1 (France)	washing with CO <sub>2</sub> and H <sub>2</sub> O
Super-Phénix 2 (France)	
SNR 2 (Germany)	
DFBR (Japan)	cleaning with high temperature argon
CDFR (UK)	
BN-1600 (Russia)	to be determined
BN-800 (Russia)	argon with steam and washing
EFR	washing with CO <sub>2</sub> and H <sub>2</sub> O
ALMR (USA)	drip drying in helium atmosphere