Overview on New RRls in China

CHEN Huiqiang
China Institute of Atomic Energy
Contents

A. China Advanced Research Reactor (CARR)
B. China Experimental Fast Reactor (CEFR)
Part A  CARR

- Reactor complex
- Design parameters
- Safety systems
- Utilization
CARR

- Tank-in-Pool
- 60 MW
- H2O coolant, D2O reflector
- Maximum thermal neutron flux:
  \[ 8 \times 10^{14} \text{ n} \cdot \text{cm}^{-2} \cdot \text{s}^{-1} \text{ (in reflector)} \]
Pool
- Plate type
- $^{235}\text{U}$ enrichment: 19.75 wt%
- 17 Fuel Assemblies (FA)
- 21 plates in each FA
  - Meat: $\text{U}_3\text{Si}_2$-$\text{Al}$, thickness=0.6mm
  - Cladding: 6061 Al alloy, thickness=0.38mm
CARR Reactor Complex

Control Rod

- Neutron absorb: Hafnium
- Shim rods: 3
- Regulating rods: 1
- Safety rods: 2
CARR Reactor Complex

Reactor Vessel

- Al alloy, life ≈ 10 years
- D = 459mm
- Separating H2O and D2O
Reactor vessel
CARR Reactor Complex

Heavy Water Tank

- $D = 2200\text{mm}$
- Material = SS
- $H_{\text{heavry water}} = 2320\text{mm}$
- $H_{\text{helium}} = 190\text{mm}$
Heavy Water Tank
Heavy Water Tank
3 Cylinders: inner + middle + outer
- $D_{\text{outer cylinder}} = D_{\text{reactor pool}}$
- Material = SS
- Decay time = 40 s
Decay Tank
Decay Tank
CARR Reactor Complex

Coolant Guiding Tank

- $D = 1364\text{mm}$
- Material = SS
- Making coolant flow stably
Coolant Guiding Tank
Coolant Guiding Tank
CARR Reactor Complex

Coolant Guiding Tank

- \( D = 1364 \text{mm} \)
- Material: SS
- Making coolant flow stably
CARR Reactor Complex

CRDM

- CRDM for safety rods: Hydraulic
- CRDM for other rods: Electromagnetic
CRDM
# CARR_____Design parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>MW</td>
<td>60</td>
</tr>
<tr>
<td>Equivalent diameter of active area</td>
<td>cm</td>
<td>39.92</td>
</tr>
<tr>
<td>Height of active area</td>
<td>cm</td>
<td>85</td>
</tr>
<tr>
<td>Maximum thermal neutron flux</td>
<td>n/ (cm².s)</td>
<td>~1.0×10^{15}</td>
</tr>
<tr>
<td>Primary coolant flow rate</td>
<td>m³/h</td>
<td>2385</td>
</tr>
<tr>
<td>Primary coolant inlet pressure</td>
<td>MPa</td>
<td>0.936</td>
</tr>
<tr>
<td>Primary coolant outlet temperature</td>
<td>°C</td>
<td>56</td>
</tr>
<tr>
<td>Depth of reactor pool</td>
<td>m</td>
<td>15.54</td>
</tr>
<tr>
<td>Inner diameter of reactor pool</td>
<td>m</td>
<td>5.5</td>
</tr>
</tbody>
</table>
CARR Safety System

Reactor Shutdown System

- Control rod falling
  Triggered by FRPS and SRPS
- Heavy water discharge
  Triggered by SRPS
## CARR—Reactor shutdown
### Protection variable of FRPS

<table>
<thead>
<tr>
<th></th>
<th>Protection Variable</th>
<th>Setting Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reactor power</td>
<td>Over setting value</td>
</tr>
<tr>
<td>2</td>
<td>Period of reactor power</td>
<td>Under setting value</td>
</tr>
<tr>
<td>3</td>
<td>Primary coolant inlet temperature</td>
<td>Over setting value</td>
</tr>
<tr>
<td>4</td>
<td>Primary coolant outlet temperature</td>
<td>Over setting value</td>
</tr>
<tr>
<td>5</td>
<td>Primary coolant inlet pressure</td>
<td>Under setting value</td>
</tr>
<tr>
<td>6</td>
<td>Primary coolant inlet flow rate</td>
<td>Under setting value</td>
</tr>
<tr>
<td>7</td>
<td>Secondary coolant inlet pressure</td>
<td>Under setting value</td>
</tr>
<tr>
<td>8</td>
<td>Dosage of coolant</td>
<td>Over setting value</td>
</tr>
<tr>
<td>9</td>
<td>Dosage above reactor pool</td>
<td>Over setting value</td>
</tr>
</tbody>
</table>
## CARR—Reactor shutdown
### Protection variable of FRPS

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Dosage of stack drainage</td>
<td>Over standard value</td>
</tr>
<tr>
<td>11</td>
<td>Radioactivity of inert gases in reactor hall</td>
<td>Over setting value</td>
</tr>
<tr>
<td>12</td>
<td>Inlet temperature of heavy water</td>
<td>Over setting value</td>
</tr>
<tr>
<td>13</td>
<td>Outlet temperature of heavy water</td>
<td>Over setting value</td>
</tr>
<tr>
<td>14</td>
<td>Heavy water flow rate</td>
<td>Under setting d value</td>
</tr>
<tr>
<td>15</td>
<td>Power supply</td>
<td>OFF</td>
</tr>
<tr>
<td>16</td>
<td>Frequency of off-site power</td>
<td>Under setting value</td>
</tr>
<tr>
<td>17</td>
<td>Pressure in operation hall</td>
<td>Over setting value</td>
</tr>
<tr>
<td>18</td>
<td>The ratio of thermal power to nuclear power</td>
<td>Over setting value</td>
</tr>
<tr>
<td>19</td>
<td>The ratio of heavy water thermal power to reactor power</td>
<td>Over setting value</td>
</tr>
</tbody>
</table>
CARR—Reactor shutdown
Protection variable of SRPS

<table>
<thead>
<tr>
<th></th>
<th>Reactor power</th>
<th>Over standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Primary coolant outlet temperature</td>
<td>Over standard value</td>
</tr>
<tr>
<td>3</td>
<td>γ dose of primary coolant</td>
<td>Over standard value</td>
</tr>
<tr>
<td>4</td>
<td>Power supply</td>
<td>OFF</td>
</tr>
</tbody>
</table>
CARR Safety System

Emergency Core Cooling System

- 2 pumps running continuously
- Cooling pool water under normal condition
- Cooling core under LOCA/LOFA condition
Fig. 1  Flow Diagram of CARR ECCS
CARR Safety System

Confinement

- 30 m × 30 m × 23 m (L × W × H)
  Reinforced concrete
- Isolated in case of accident so as to retaining rad-gas for some 12 hours
- Be able to withstand SSE
- Leak-rate ≯ 5 %v/d
CARR Utilization

21 vertical tubes and 9 beam tubes for:

- Neutron Scattering
- RI production
- Neutron activation analysis
- Fuel / material irradiation test
- Silicon NTD
CARR

2010,5,13
First critical reached

2011,9,22
Phase B commission finished
Part B  CEFR

- Reactor Block
- Design parameters
- Safety systems
CEFR REACTOR BLOCK

- Rotate plug
- Support of pp
- Barrel of core
- Primary pipe
- Lower grid
- Melt bed
- Fuel change device
- CRDM
- Support of I HX
- Reactor shielding
- Main and guard vessel
- Inner Support of reactor
- Heat preservation
CEFR

- Pool type
- 65 MW t / 25 MW e
- Coolant = Sodium
<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel subassembly</td>
<td>81</td>
</tr>
<tr>
<td>Stainless steel rod</td>
<td>1</td>
</tr>
<tr>
<td>Stainless steel reflector subassembly</td>
<td>37</td>
</tr>
<tr>
<td>Stainless steel reflector rod</td>
<td>132</td>
</tr>
<tr>
<td>Stainless steel reflector rod</td>
<td>167</td>
</tr>
<tr>
<td>Shielding subassembly</td>
<td>230</td>
</tr>
<tr>
<td>Storage position for spent fuel subassembly</td>
<td>56</td>
</tr>
<tr>
<td>Safety subassembly</td>
<td>3</td>
</tr>
<tr>
<td>Regulation subassembly</td>
<td>2</td>
</tr>
<tr>
<td>Compensation subassembly</td>
<td>3</td>
</tr>
</tbody>
</table>
- 81 hexagonal Fuel Assemblies (FA)
- 61 rods in each FA
- $^{235}$U enrichment: 64.4 wt%
- Meat: UO$_2$ → U-Pu dioxide
- Cladding: SS
- D=6mm
### CEFR Reactor block

**Control Rod Assembly**

- **Shim rod assembly:** 3 (B10 enrichment 91%)
- **Regulating rod assembly:** 2 (10%)
- **Safety rod assembly:** 3 (91%)
- **Each assembly consists of:** 7 rods
- **Neutron absorb:** $\text{B}_4\text{C}$
- **Cladding:** SS
• 336 SS Reflector Assemblies (RA)
• 2 types
  A: 7 rod (d=20mm) in each RA;
  B: 1 rod (d=54mm) in each RA
• In the future, the 3 inner circles of RAs will be replaced by conversion assemblies for fuel breeding research
• 230 hexagonal Shielding Assemblies (SA)
• Each assembly consists of 7 rods
• Rod Meat:
  \[ \text{B}_4\text{C} \quad (\text{B10 enrichment}=19.8\%) \]
  \[ \text{D}=16.2\text{mm} \]
• Rod clad: SS, D=19.2
• 8 CRDMs, one for one CRA
• Type A for shim and regulating rod
  Type B for safety rod
CEFR---CRDM
CEFR Reactor block

Reactor Vessel

- $H=12765$
  - main vessel: $d=7960\text{mm}, t=25\text{mm}$
  - guard vessel: $d=8185\text{mm}, t=25\text{mm}$
- PCS loops (2) in it, including:
- 2 pumps, 4 intermediate heat exchangers
- 2 independent heat exchangers for RHRS
## CFER---Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Power</td>
<td>MW</td>
<td>65</td>
</tr>
<tr>
<td>Electric Power</td>
<td>MW</td>
<td>20</td>
</tr>
<tr>
<td>Plant life</td>
<td>year</td>
<td>30</td>
</tr>
<tr>
<td>Bum-up, first load max.</td>
<td>MWd/t</td>
<td>60000</td>
</tr>
<tr>
<td>Bum-up, target max.</td>
<td>MWd/t</td>
<td>100000</td>
</tr>
<tr>
<td>Fuel exchange</td>
<td>Day</td>
<td>80</td>
</tr>
<tr>
<td>Fuel (First Loading)</td>
<td></td>
<td>UO2</td>
</tr>
<tr>
<td>Primary loop type</td>
<td></td>
<td>Pool</td>
</tr>
<tr>
<td>Number of circuits per loop</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Number of IHX per circuit</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>MPa</td>
<td>14</td>
</tr>
</tbody>
</table>
• FSS + SSS, diversities include:
(1) FSS is equipped with magnetic damper
   SSS is equipped with electromagnetic clutch
(2) FFS is actuated by motor power-off
   SSS is actuated by clutch power-off
(3) FSS rod falling by gravity
   SSS rod falling by gravity and spring
And so on
• 2 independent reactor protection systems. Variables are:

- period, power, outlet temperature, liquid Na level in main vessel, primary flow-rate, secondary flow-rate, feed-water loss of SG, closedown of turbine valve, loss of power supply, earthquake, etc.
• 2 loops, capacity of each=0.525MW
• In the accident condition, reactor residual heat will be transferred to the hot sodium zone by means of primary pump inertia and natural circulation, and then to intermediate loop through independent heat exchangers located in the hot sodium zone, and finally to the atmosphere through air coolers.
CEFR Safety System

Containment System

consists of 3 confining boxes and the confinement wherein the 3 boxes located.
CEFR Safety System

Containment System --- Confinement

- retain and sedimentate the radioactive material
- concrete structure (thickness 1m)
  \(36m \times 36m \times 57m\) (L \(\times\) W \(\times\) H)
- Leakage rate is \(\leq 5 \Delta v/v/d\) under 100Pa
When argon pressure reactor vessel reaches 0.06MPa, the liquid-sealing device opens to transfer argon to room 302 for temporary storage and decay, and then to the chimney through ventilation system. Leakage rate of room 302 is less than 4% Δv/v/d(0.03MPa).
• Reactor cap, carbon steel.
• When the radioactive level exceeds the setting value, emergency ventilation system starts up to replace the normal ventilation system by which the radioactive argon and Na aerosol can be prevented from escaping into the confinement.
• Groove is laid beneath the pipes and equipments in this BOX
• In case of accident, the leaked Na will flowed into the groove where isolated space will be formed so that the Na fire can be put out automatically.
CEFR

- First critical  2010/7/21
- Electricity generation  2011/7/21
谢谢！

Thanks for your attention!