Overview on New RRs in China

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Contents

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

Part A   CARR

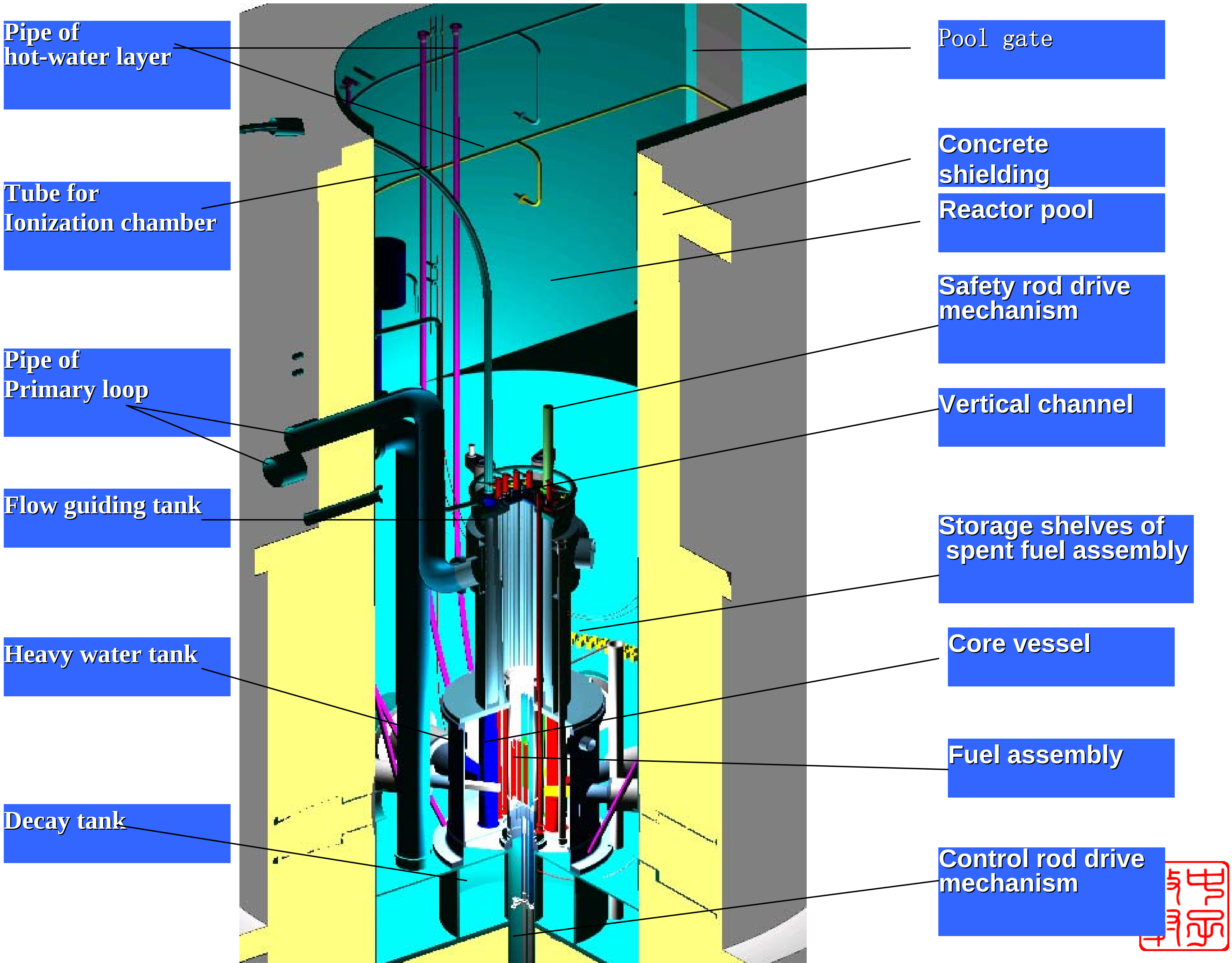
- Reactor complex
- Design parameters
- Safety systems
- Utilization

CARR

- Tank- in-Pool
- 60 MW
- H_2O coolant, D_2O reflector
- Maximum thermal neutron flux:

  8×10^{14} $n \cdot cm^{-2} \cdot s^{-1}$ (in reflector)

Pool


Pipe of
hot-water layer
Tube for
Ionization chamber
Pipe of
Primary loop
Flow guiding tank
Heavy water tank
Decay tank
Pool gate
Concrete
shielding
Reactor pool
Safety rod drive
mechanism
Vertical channel
Storage shelves of
spent fuel assembly
Core vessel
Fuel assembly
Control rod drive
mechanism

CARR_____Reactor Complex

Fuel

- Plate type
- ^{235}U enrichment: 19.75 wt%
- 17 Fuel Assemblies (FA)
- 21 plates in each FA

  Meat: U_3Si_2-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 H_2O and D_2O

Reactor vessel

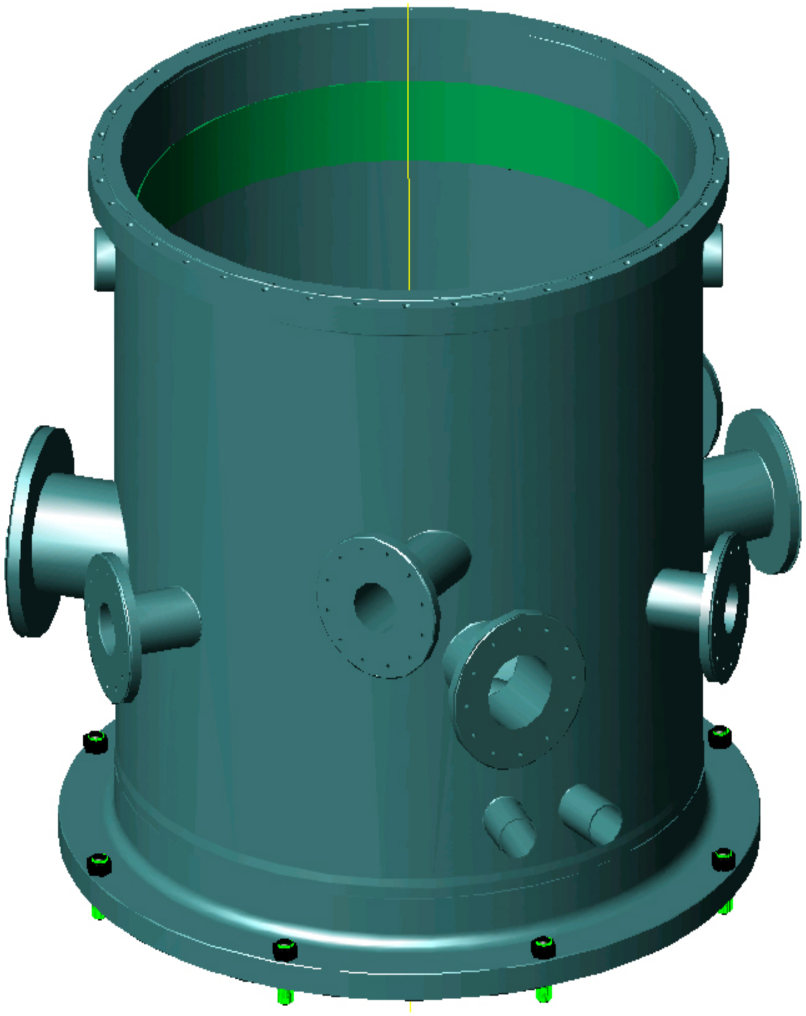
CARR______Reactor Complex

Heavy Water Tank

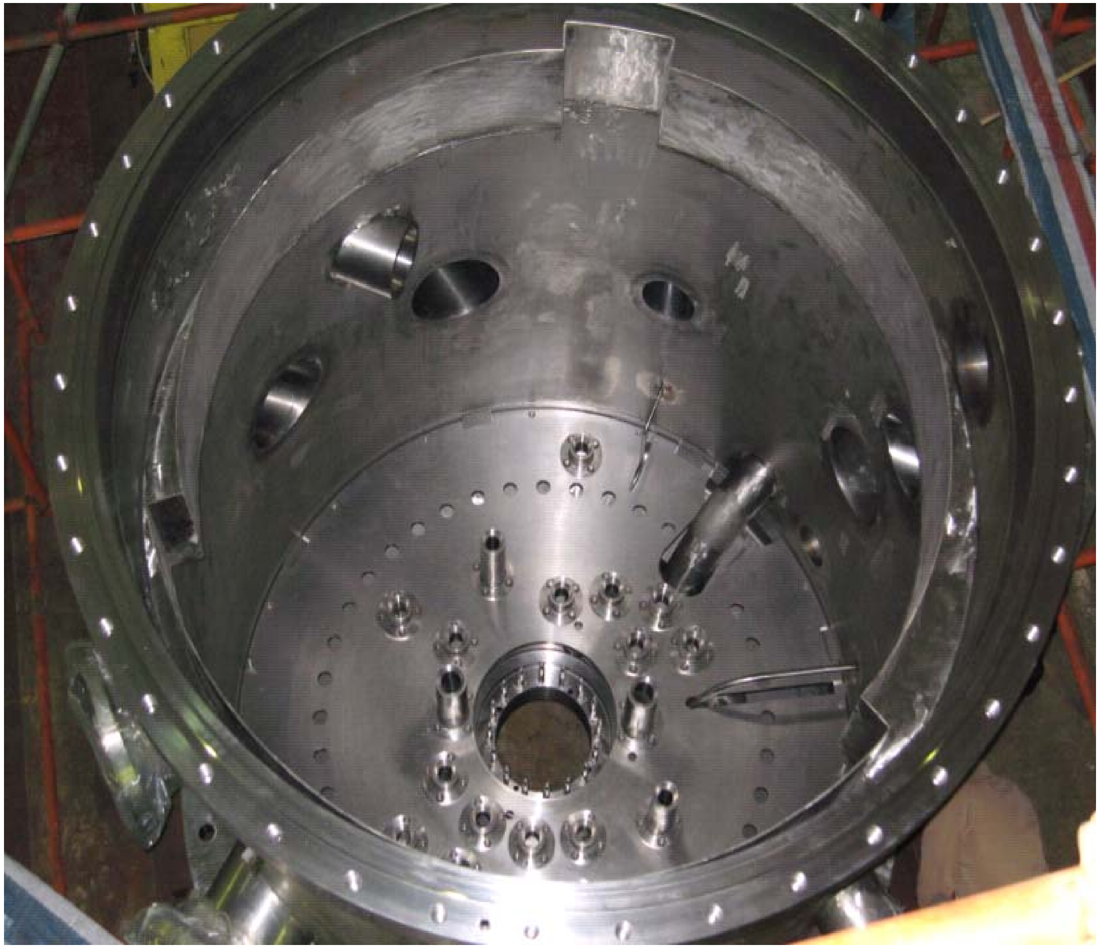
- D = 2200mm
- Material= SS
- $H_{\text{heavry water}}$ =2320mm

  H_{heliume} =190mm

Heavy Water Tank



Heavy Water Tank

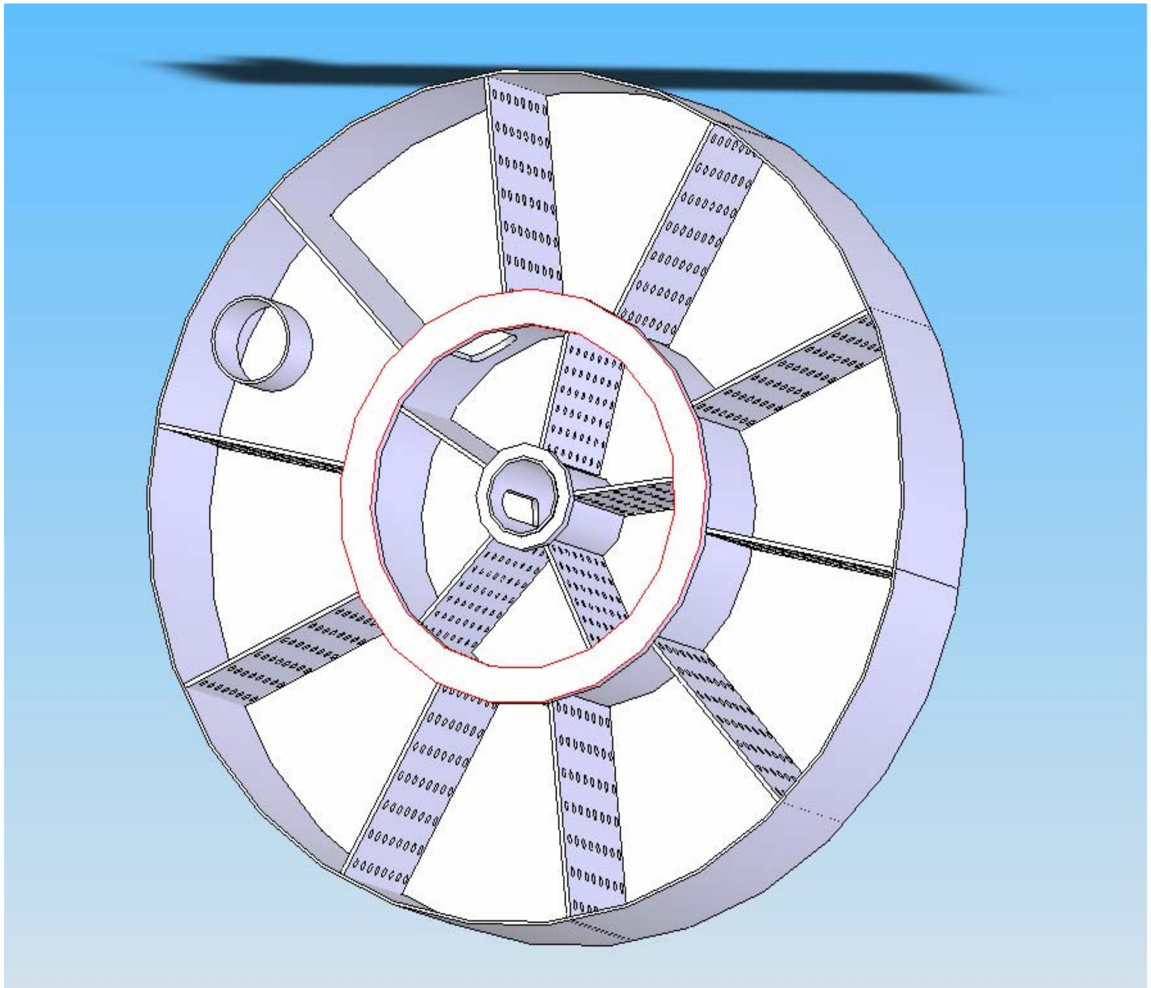


CARR_____Reactor Complex

Decay Tank

- 3 Cylinders: inner + middle + outer
- $D_{\text{outer cylinder}} = D_{\text{reactor pool}}$
- Material= SS
- Decay time=40 s

Decay Tank



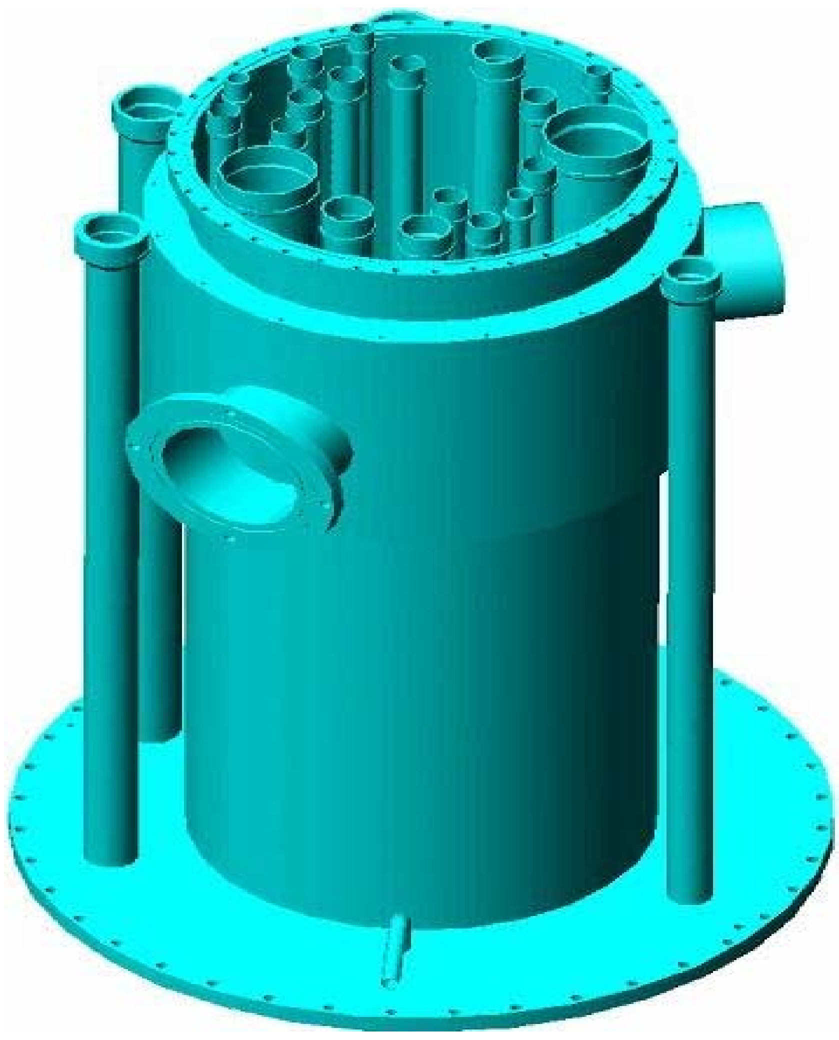
Decay Tank

CARR______Reactor Complex

Coolant Guiding Tank

- D = 1364mm
- Material= SS
- Making coolant flow stably

Coolant Guiding Tank



Coolant Guiding Tank

CARR______Reactor Complex

Coolant Guiding Tank

- D = 1364mm
- Material= SS
- Making coolant flow stably

CARR______Reactor Complex

CRDM

- CRDM for safety rods: Hydraulic
- CRDM for other rods: Electromagnetic

CRDM

CARR______Design parameters

Power	**MW**	**60**
Equivalent diameter of active area	**cm**	**39.92**
Height of active area	**cm**	**85**
Maximum thermal neutron flux	**n/（cm^2.s）**	**$\sim 1.0\times 10^{15}$**
Primary coolant flow rate	**m^3/h**	**2385**
Primary coolant inlet pressure	**MPa**	**0.936**
Primary coolant outlet temperature	**°C**	**56**
Depth of reactor pool	**m**	**15.54**
Inner diameter of reactor pool	**m**	**5.5**

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

1	**Reactor power**	**Over setting value**
2	**period of reactor power**	**Under setting value**
3	**Primary coolant inlet temperature**	**Over setting d value**
4	**Primary coolant outlet temperature**	**Over setting value**
5	**Primary coolant inlet pressure**	**Under setting value**
6	**Primary coolant inlet flow rate**	**Under setting value**
7	**secondary coolant inlet pressure**	**Under setting value**
8	**Dosage of coolant**	**Over setting value**
9	**Dosage above reactor pool**	**Over setting value**

CARR—Reactor shutdown

Protection variable of FRPS

10	**Dosage of stack drainage**	**Over standard value**
11	**Radioactivity of inert gases in reactor hall**	**Over setting value**
12	**Inlet temperature of heavy water**	**Over setting value**
13	**Outlet temperature of heavy water**	**Over setting value**
14	**Heavy water flow rate**	**Under setting d value**
15	**Power supply**	**OFF**
16	**Frequency of off-site power**	**Under setting value**
17	**Pressure in operation hall**	**Over setting value**
18	**The ratio of thermal power to nuclear power**	**Over setting value**
19	**The ratio of heavy water thermal power to reactor power**	**Over setting value**

CARR—Reactor shutdown
Protection variable of SRPS

1	**Reactor power**	**Over standard value**
2	**Primary coolant outlet temperature**	**Over standard value**
3	**γ dose of primary coolant**	**Over standard value**
4	**Power supply**	**OFF**

CARR______Safety System

Emergency Core Cooling System

- 2 pumps running continuously
- Cooling pool water under normal condition
- Cooling core under LOCA/LOFA condition

CARR---ECCS

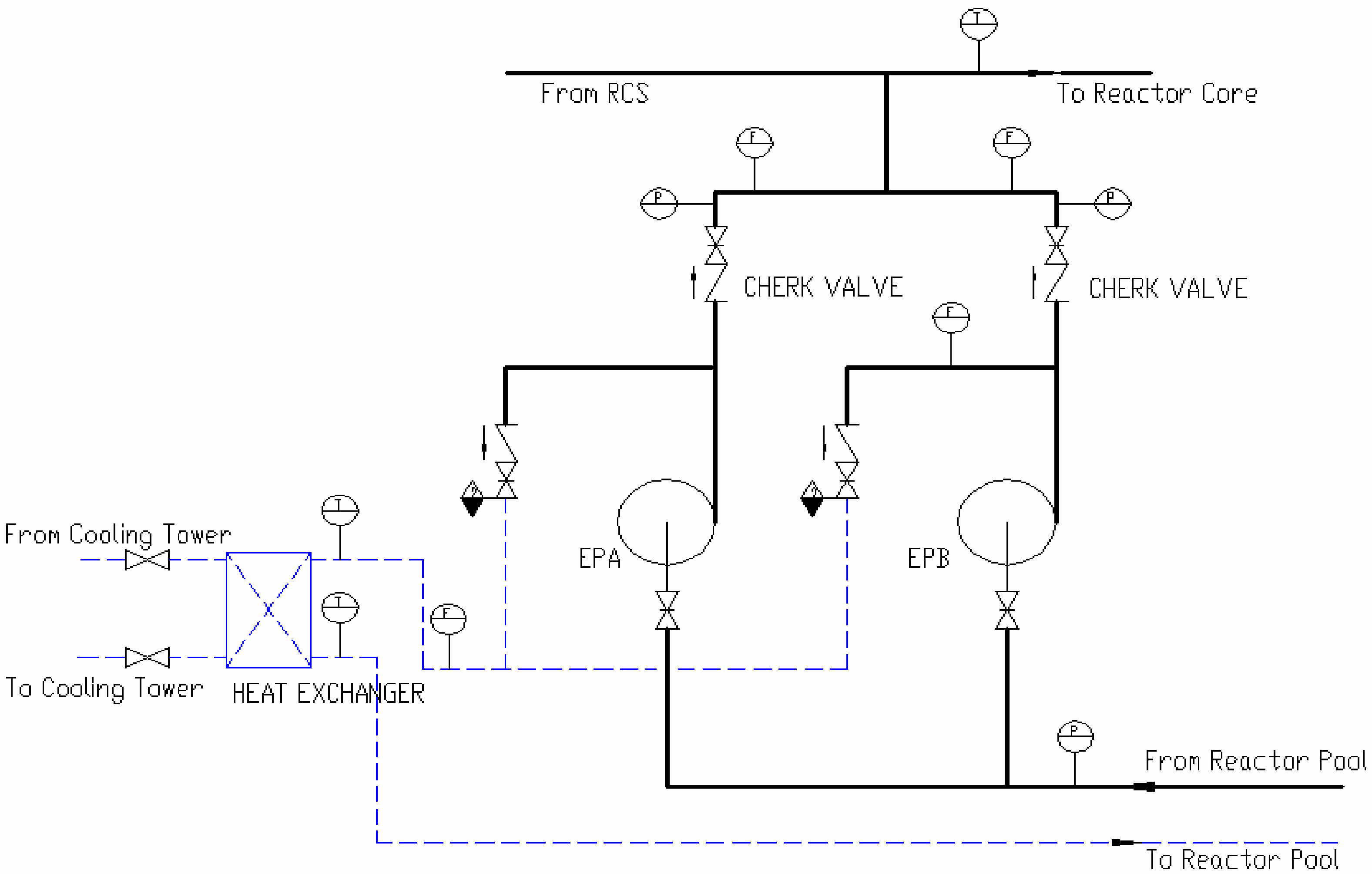


Fig.1 Flow Diagram of CARR ECCS

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

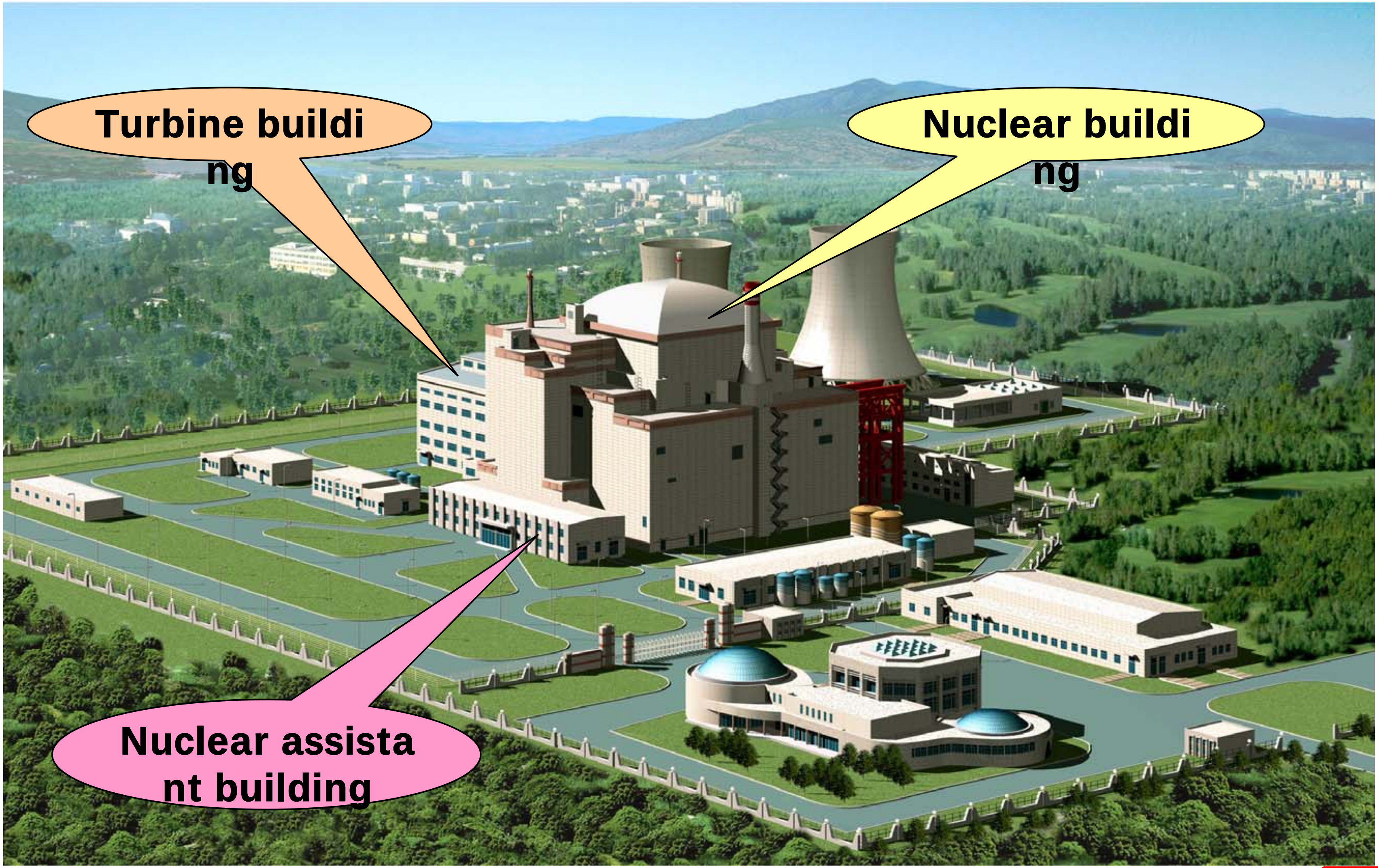
2011,9,22

Phase B commission finished

Part B   CEFR

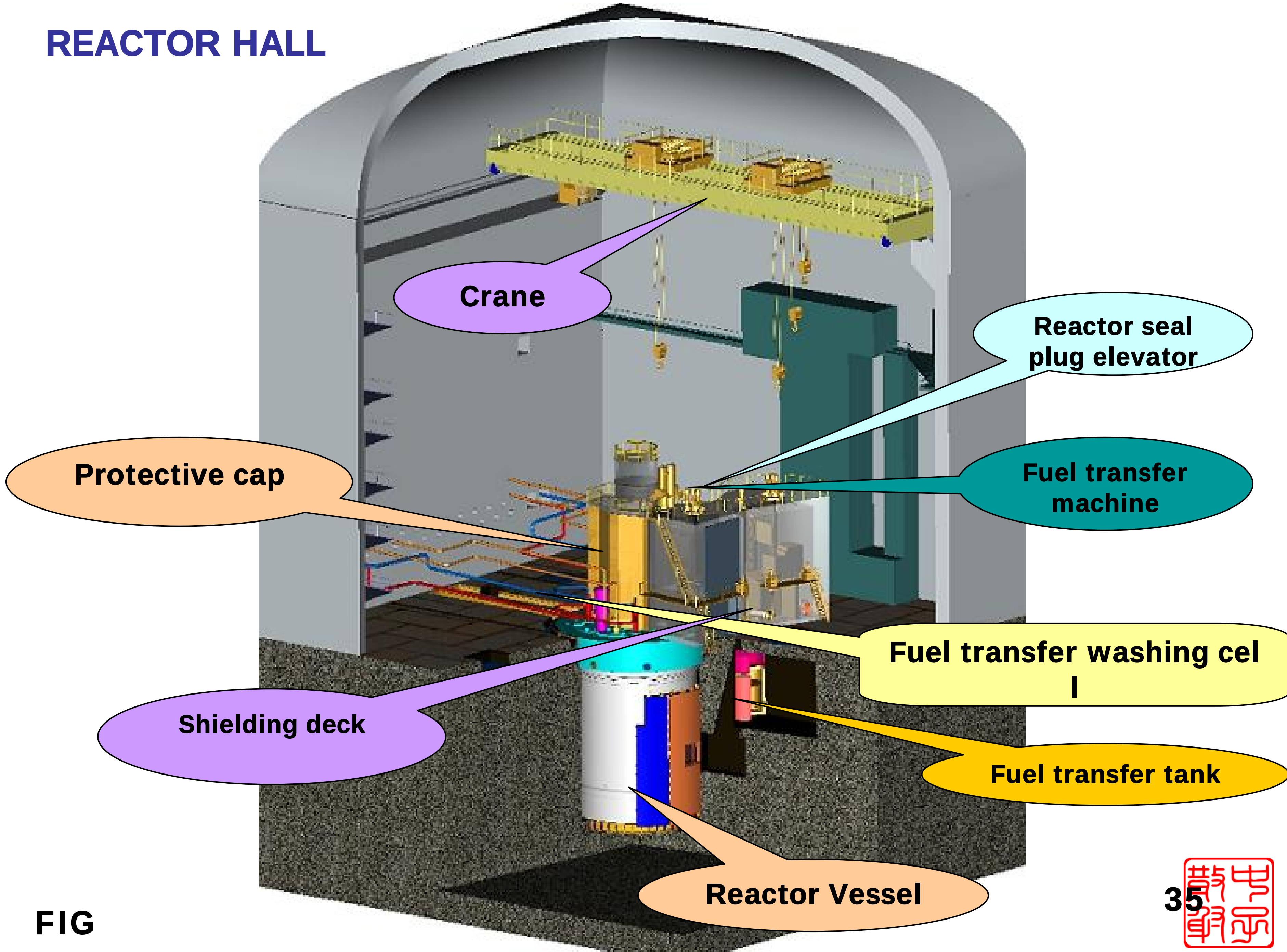
- Reactor Block
- Design parameters
- Safety systems

COMPUTER IMAGINATION OF CEFR



Building

REACTOR HALL



FIG

CEFR REACTOR BLOCK

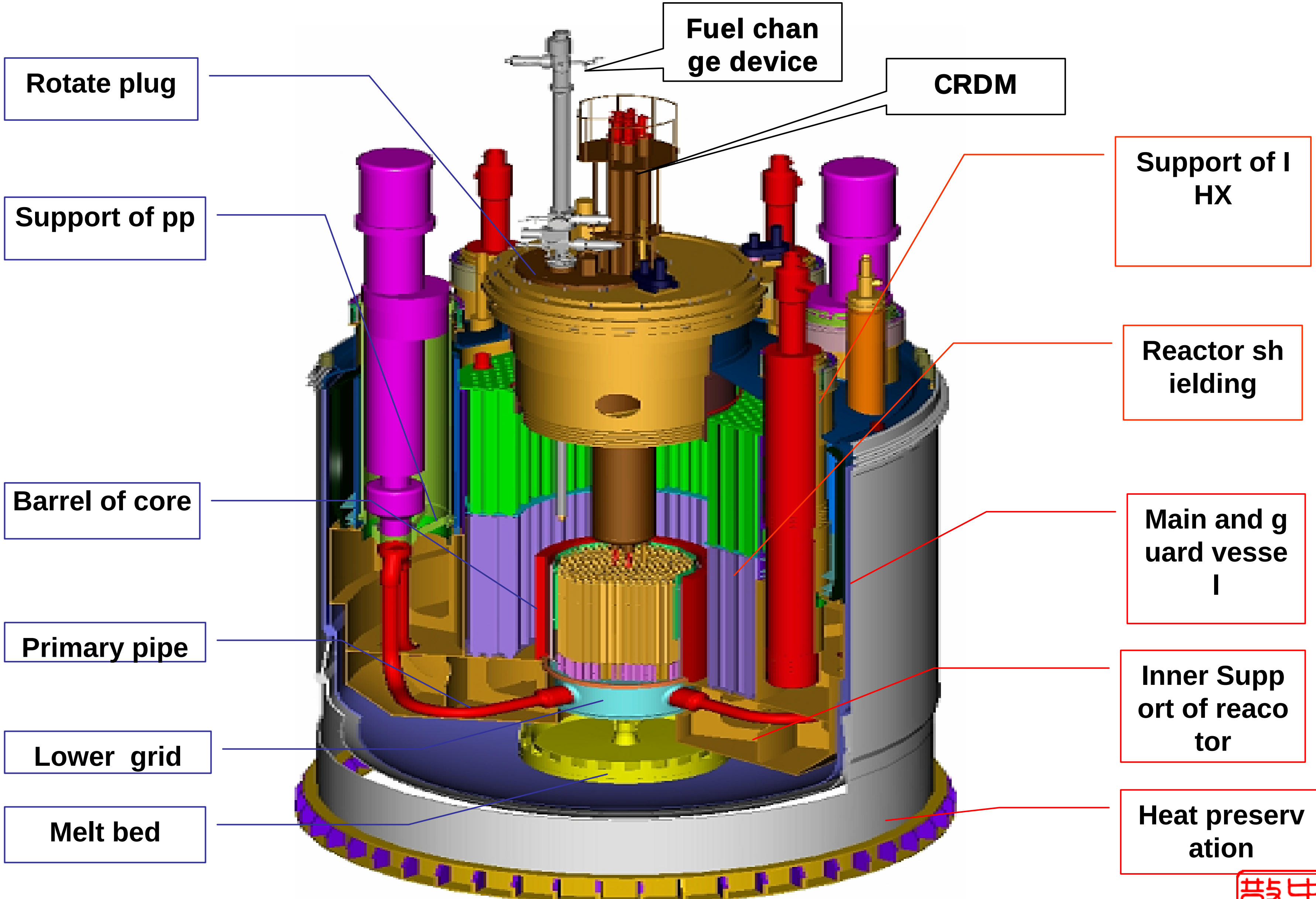
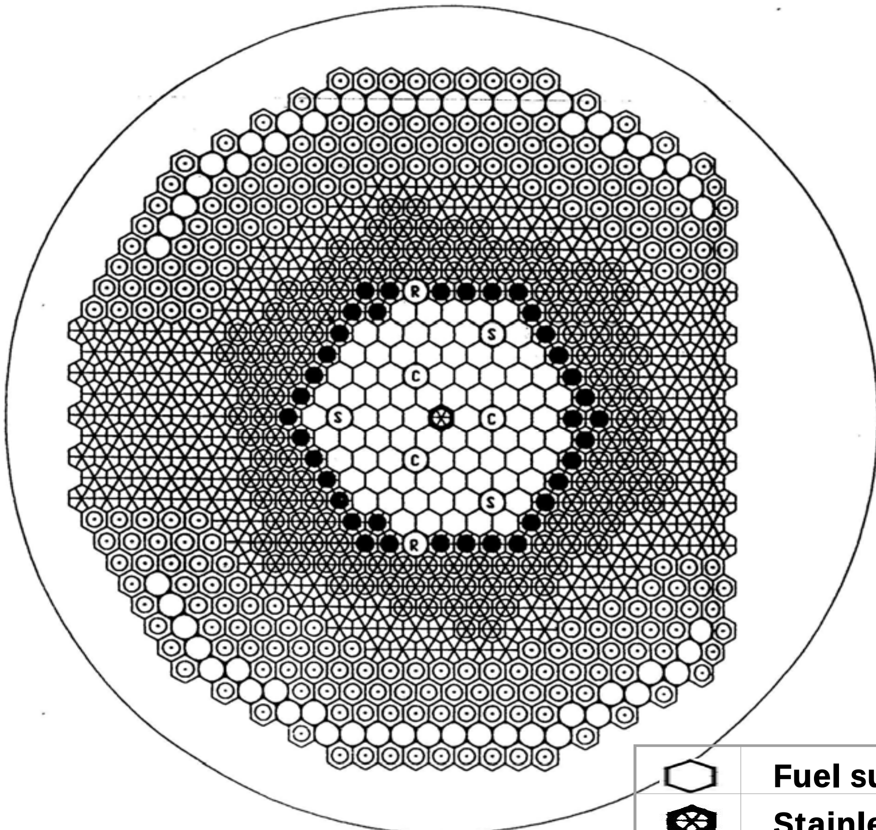


FIG 1

CEFR

- Pool type
- 65 MW t / 25 MW e
- Coolant = Sodium

CEFR Core



Core Fig

Fuel subassembly	81
Stainless steel rod	1
Stainless steel reflector subassembly	37
Stainless steel reflector rod	132
Stainless steel reflector rod	167
Shielding subassembly	230
Storage position for spent fuel subassembly	56
Safety subassembly	3
Regulation subassembly	2
Compensation subassembly	3

CEFR______Reactor block

Fuel

- 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 enrichment91%)
- Regulating rod assembly : 2 (10%)
- Safety rod assembly : 3 (91%)
- Each assembly consists of 7 rods
- Neutron absorb: B_4C

Cladding : SS

CEFR______Reactor block

Reflector

- 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

CEFR_____Reactor block

Shielding Assembly

- 230 hexagonal Shielding Assemblies (SA)
- Each assembly consists of 7 rods
- Rod Meat:

  B_4C (B10 enrichment=19.8%)

  D= 16.2mm
- Rod clad: SS, D=19.2

CEFR______Reactor block

CRDM

- 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=7960mm,   t=25mm

  guard vessel: d=8185mm,   t=25mm
- PCS loops (2) in it , including:
- 2 pumps, 4 intermediate heat exchangers
- 2 independent heat exchangers for RHRS

CFER---Parameters

Thermal Power	**MW**	**65**
Electric Power	**MW**	**20**
Plant life	**year**	**30**
Bum-up, first load max.	**MWd/t**	**60000**
Bum-up, target max.	**MWd/t**	**100000**
Fuel exchange	**Day**	**80**
Fuel (First Loading)		**UO2**
Primary loop type		**Pool**
Number of circuits per loop		**2**
Number of IHX per circuit		**2**
Steam pressure	**MPa**	**14**

CEFR______ Safety System

Reactor Shutdown System

- 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

CEFR______ Safety System

Reactor Shutdown System

- 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.

CEFR______ Safety System

Residual Heat Removal System

- 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.

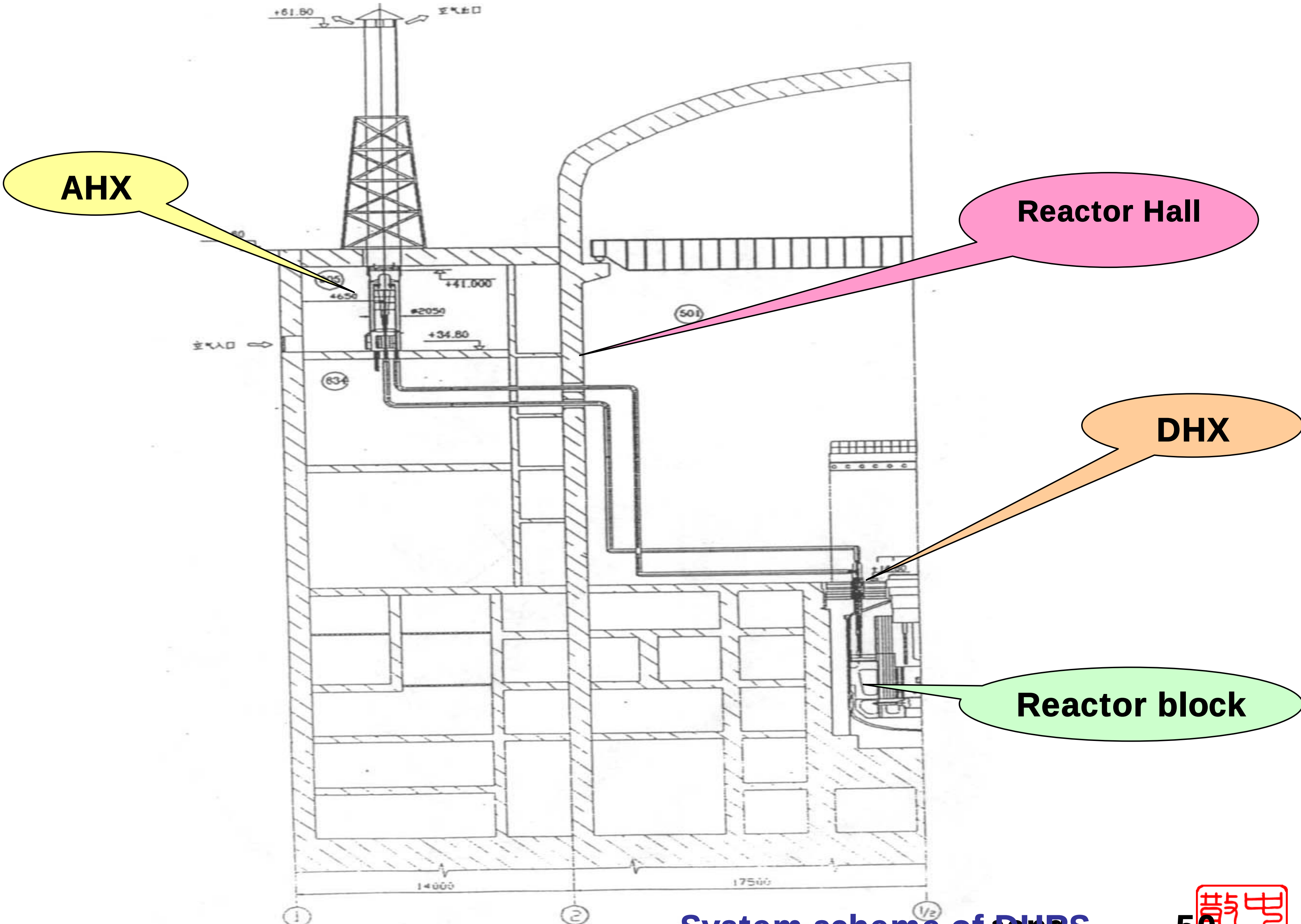


图 6.3—1 事故余热排出系统总体布置图

System scheme of DHRS

Tang

CEFR______ Safety System

Containment System

consists of 3 confining boxes and the confinement wherein the 3 boxes located.

36m×36m×57m（L×W×H）

CEFR______ Safety System

Containment System--- Confinement

- retain and sedimentate the radioactive material
- concrete structure (thickness 1m)
  36m×36m×57m（L×W×H）
- Leakage rateis ≮5Δv/v/d under 100Pa

CEFR______ Safety System

Containment System--- BOX1

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% Δ v/v/d(0.03MPa).

CEFR______ Safety System

Containment System--- BOX2

- 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.

CEFR______ Safety System

Containment System--- BOX2

- 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!

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