中国原子能科学研究院
CNNC CHINA INSTITUTE OF ATOMIC ENERGY

Workshop on Current and Emerging Methods for Optimising Safety and Efficiency in Nuclear Decommissioning,
7th - 9th February 2017, Sarpsborg, Norway

Challenges of HWRR Decommissioning

ZHOU Yidong
China Institute of Atomic Energy

Contents

Part 1, Challenges of HWRR decommissioning

1. Introduction to HWRR

2. Decommissioning planning

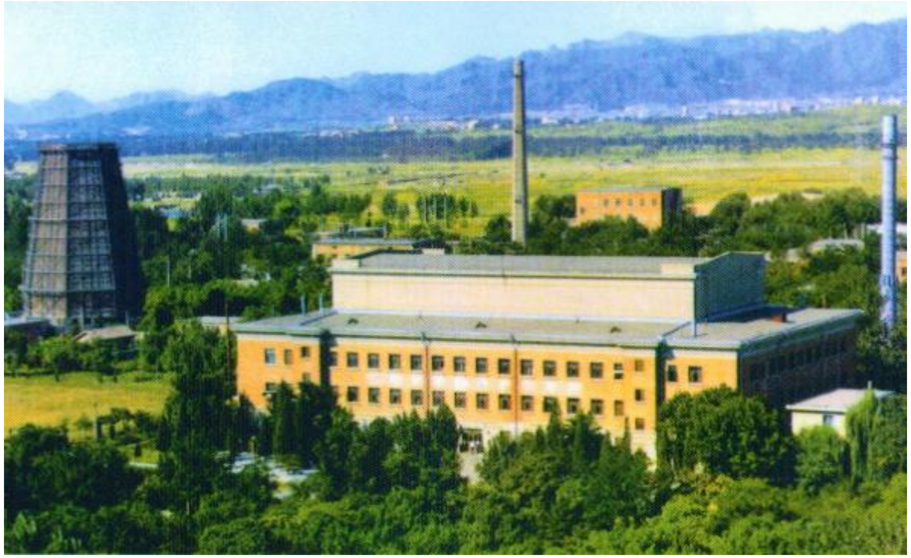
3. Challenges

Heavy Water Research Reactor (HWRR)

- It is the first nuclear reactor in China.
- It reached first criticality in 1958.
- It is located in suburb of Beijing, Capital of China.
- It is a 10MW multi-purpose research reactor.
- It is cooled and moderated by D2O
- It has been operated for 49 years.
- It was permanently shut down at the end of 2007.

HWRR has made great contributions to development of nuclear science and technology in China.

1. Introduction to HWRR



HWRR reactor building and cooling tower

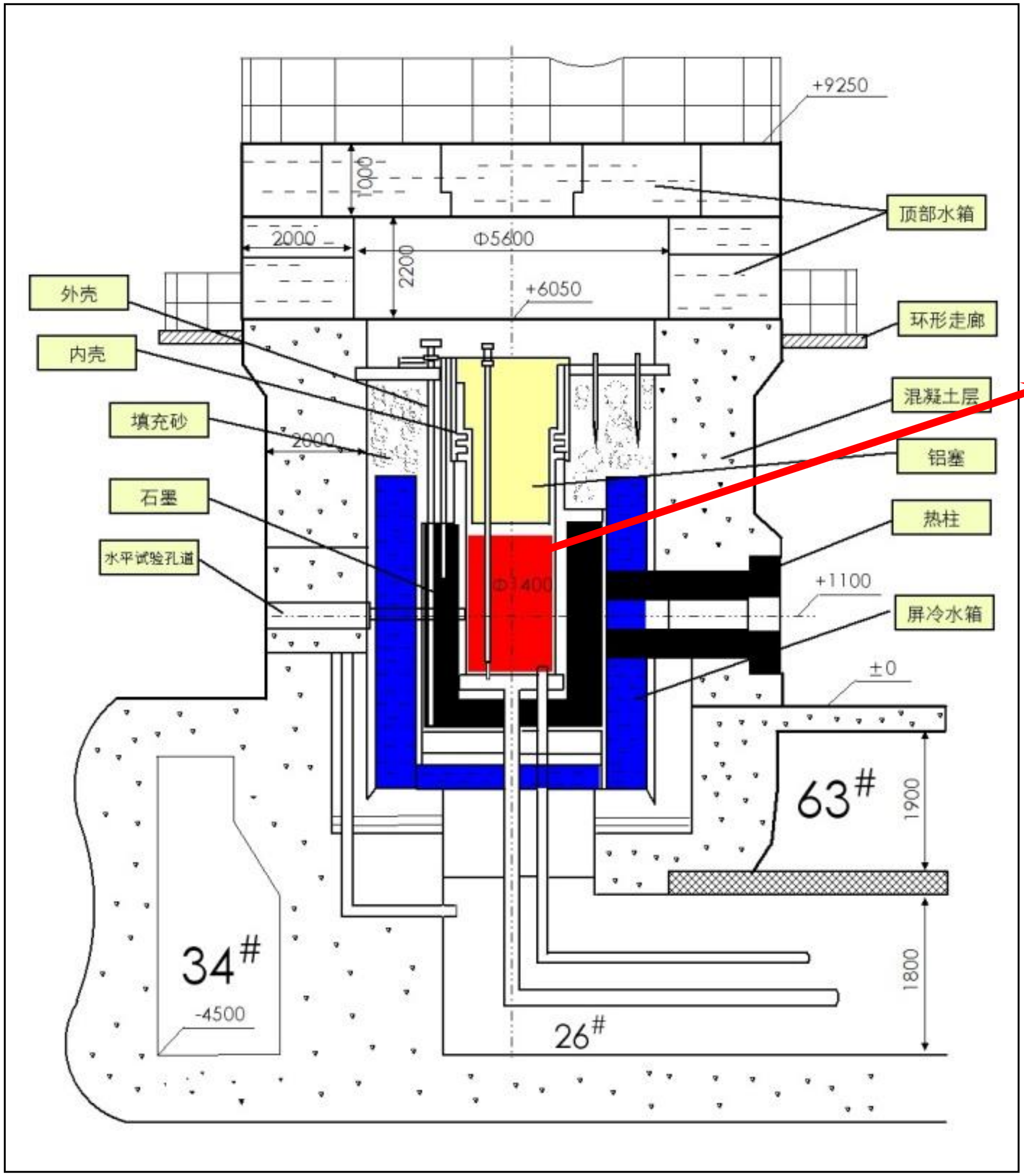
HWRR reactor hall

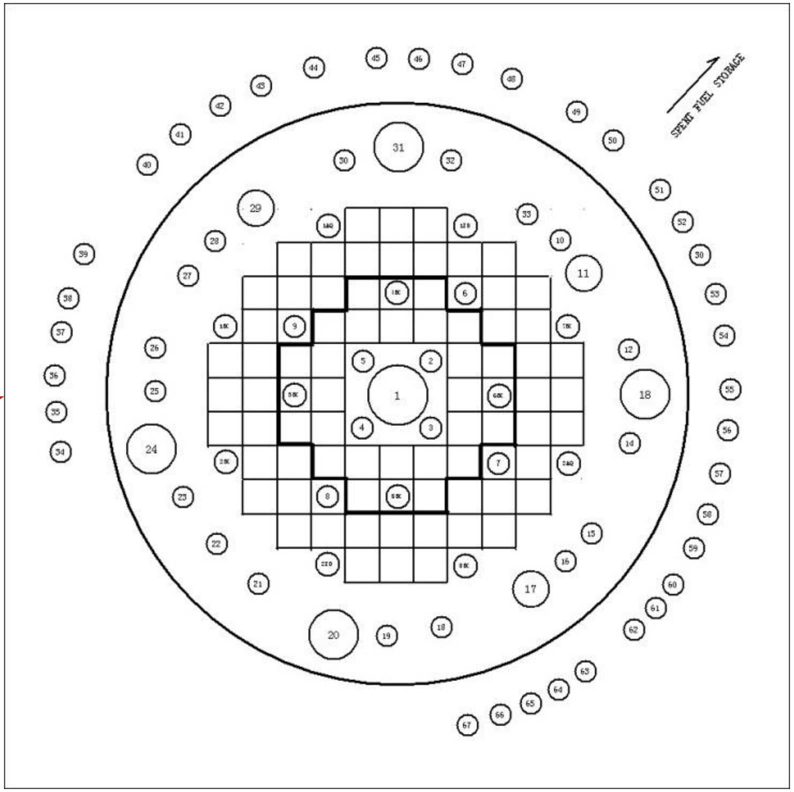
1. Introduction to HWRR

✓ **Application**

- Nuclear physics
- Reactor physics and thermal hydraulics
- Radiation protection and monitoring
- Irradiation of materials including nuclear fuel
- Neutron activation analysis (NAA)
- Production of radioactive isotopes (RI)
- Technical services for NPPs
- Reactor operation management
- Personnel training

1. Introduction to HWRR





Section of HWRR reactor

1. Introduction to HWRR

Structure	Material	Quantity
Fuel assembly		72
Fuel	UO_2	
Fuel rod		12
Cladding	Zr-2	
Safety rod	Cd	2
Shim rod	Cd	8
Automatic rod	Cd	2
Inner vessel	Al alloy	1
Outer vessel	C.S.	1
Vertical irradiation tubes inside of inner vessel	Al alloy	33
Vertical irradiation tubes in graphite reflector	Al alloy	34
Horizontal neuron beam	Al alloy	6
Thermal column	Al alloy	1

1. Introduction to HWRR

Parameters	Unit	Value
Rated thermal power	MW	10
Strengthened thermal power	MW	15
Max. thermal neutron flux	n/cm2.s	2.6E14
Max. fast neutron flux	n/cm2.s	1.4E13
Lattice	cm	9.2
Fuel height	cm	100
U-235 enrichment	%	3
Graphite in reflector	kg	26,000
Graphite in thermal column	kg	12,000
Thickness of concrete	m	2
Density of concrete	g/cm3	3.6

1. Introduction to HWRR

✓ Reactor modification: 1979-1983

- Change of inner vessel
- Change of two main heat exchangers
- Chemical decontamination of primary coolant system
- Core conversion: Fuel number: 84 → 72

  Lattice size (cm) : 13×13 → 9.2×9.2

  Fuel: Metal U(2%) → Ceramic UO_2(3%)

  Fuel height(cm): 124.3 →100

  Cladding: Al → Zr-2
- Primary coolant flow rate(m^3/h): 400 → 640
- Secondary coolant flow rate(m^3/h): 1000 → 1800

2. Decommissioning planning

- Since long operation, all equipment are aged and outdated, not good for safety consideration.
- The license of HWRR expired on 31 Dec. 2007, therefore HWRR was permanently shut down at the end of 2007.
- As a replacement, a new research reactor, China Advanced Research Reactor (CARR) with thermal power 60 MW, was constructed and attained criticality in 2010 at CIAE
- As national policy, immediate dismantling is the preferred strategy for a nuclear facility after cessation of operation.

2. Decommissioning planning

✓ **Objectives**

- **After short term transition period following permanent shutdown , HWRR decommissioning will be implemented for restricted release.**

  The reactor building with central control room and partial biological shielding concrete will remain.

- **Minimizing waste volumes generated.**
- **Minimizing personnel exposure and environmental impact.**
- **Minimizing project cost.**
- **Maximizing reuse rate of equipment and site.**

2. Decommissioning planning

✓ **Significance**

- **Safe decommissioning of HWRR with minimized environmental impact is an important and sensitive issue in Beijing, capital of China.**
- **Experience and expertise gained through HWRR decommissioning will be very valuable for decommissioning of other nuclear facilities in China.**
- **Decommissioning of HWRR will enforce sustainable development and harmonization between human and environment.**

2. Decommissioning planning

✓ **National support**

- **HWRR decommissioning has been included in the governmental plans for the period of 2011-2015, 2016 – 2020 and 20-year long-term plan.**
- **A project on preparation for HWRR decommissioning was implemented.**
- **A project on transportation of HWRR spent fuel assemblies was implemented.**
- **A project proposal on HWRR decommissioning was submitted to government for approval.**
- **A project proposal on transportation of remaining HWRR spent fuel assemblies was submitted to government for approval.**

2. Decommissioning planning

✓ **Decommissioning activities- Stage 1**

- Construction/modification of supporting systems, workshops and site preparation.
- Drainage of water in spent fuel pool & low-level waste water containing tritium
- Decontamination and dismantling of 3 waste water storage tanks, radiochemical lab. and radioisotope lab. at the same site.
- Dismantling of cooling tower.
- Cutting of pipes, dismantlement of components, disassembly/packaging of big equipment
- Procurement of equipment for Stage 2 and 3.
- R&D and testing on techniques for Stage 2&3.

2. Decommissioning planning

✓ Decommissioning activities- Stage 2

- Decontamination and dismantling of 4 hot cells.
- Decontamination and dismantling of primary coolant system.
- Decontamination and dismantling of other systems in the basement.
- Cutting of pipes, dismantlement of components, disassembly/packaging of big equipment
- Procurement of equipment for Stage 3.
- R&D and testing on techniques for Stage 3.

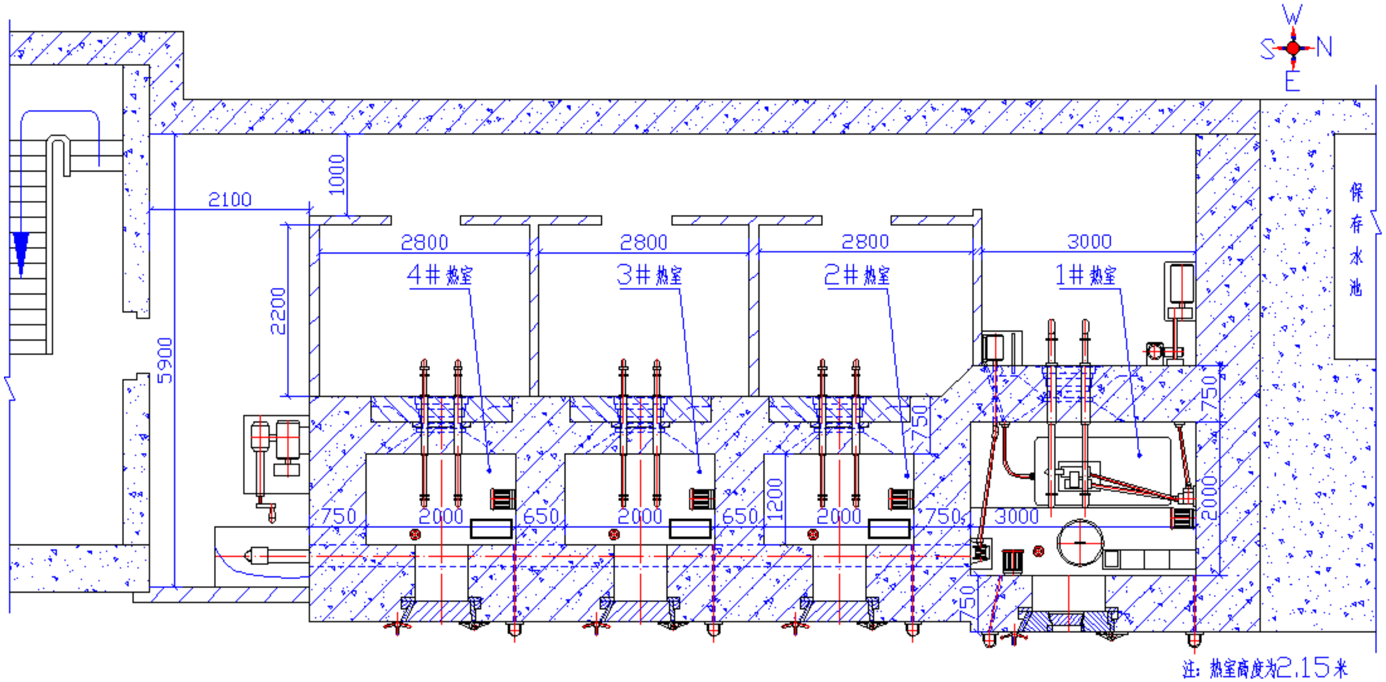
2. Decommissioning planning

✓ **Decommissioning activities- Stage 3**

- Dismantling of internal components of HWRR, including graphite reflector and thermal column.
- Partially dismantling of biological shielding concrete.
- Dismantling the supporting systems (ventilation, sewage, monitoring systems, workshops).
- Cutting of pipes, dismantlement of components, disassembly/packaging of big equipment.
- Reconstruction of HWRR reactor block.
- Decontamination of reactor building surface.
- Final survey.
- Restoration of reactor site.

3. Challenges

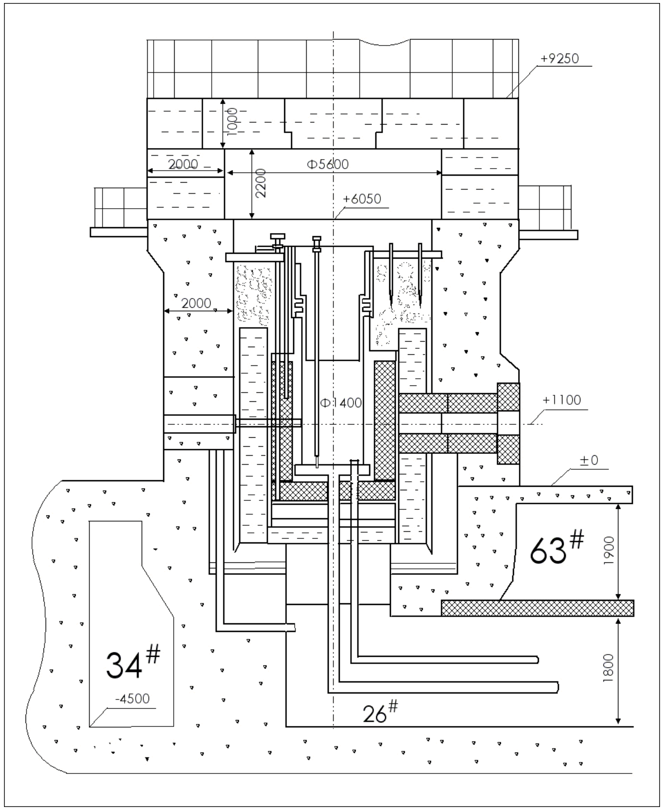
- ✓ 4 hot cells
- Underground
- Heavy contamination
- Operation ceased since end of 1970s
- Systems and equipment out of work
- Limited space



3. Challenges

✓ Heavy concrete biological shield

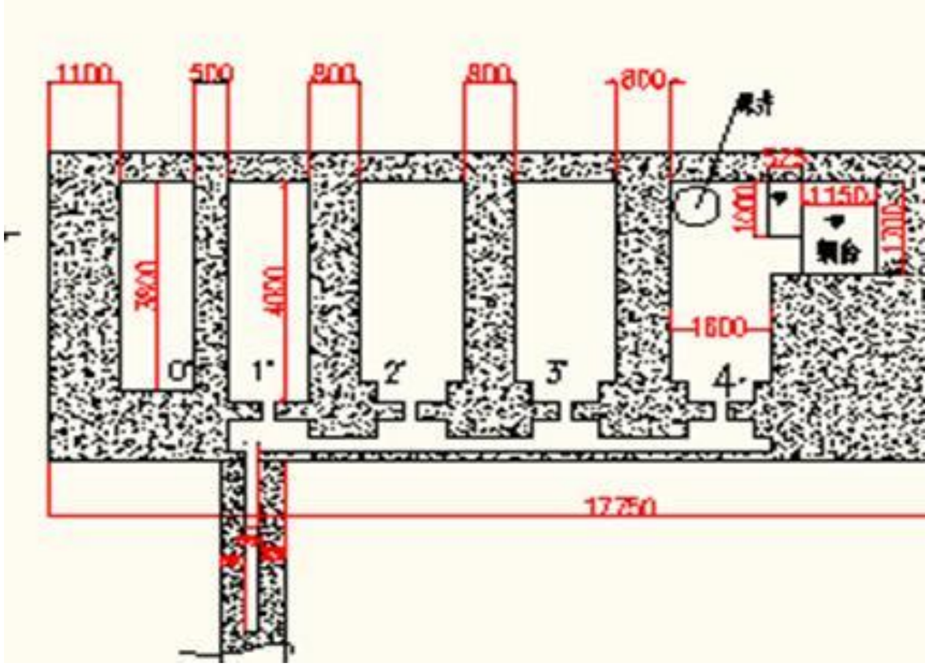
- 6 neutron beams
- 1 thermal column
- Partially dismantling:
  - Integrity
  - Safety
  - Cost
- Waste minimization
- To be used as a monument



3. Challenges

✓ **Spent fuel storage pool**

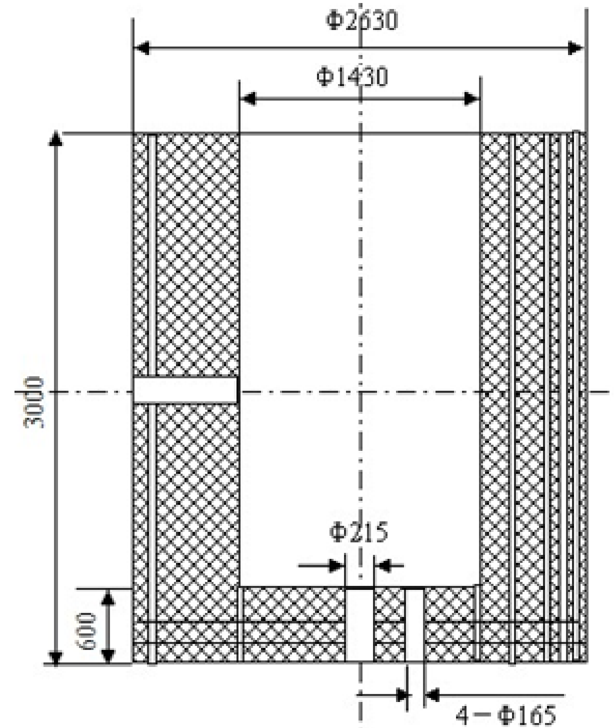
- Inside of reactor building
- 4 wet basins and 1 dry basin
- Canal connecting reactor and pool
- S.S lining
- No purification system
- Low visibility
- Thick sludge at the bottom
- Possible metal U fuel cells, irradiated samples or irradiated radio-isotope targets

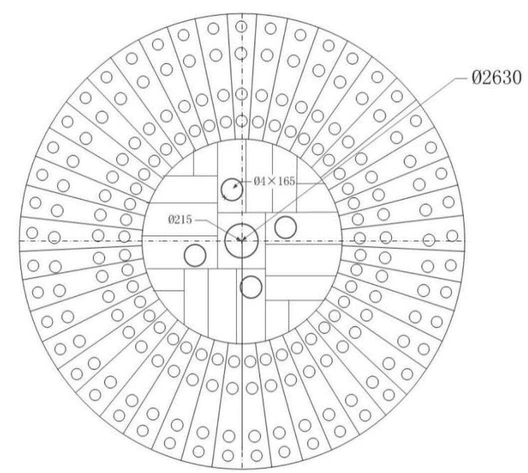


3. Challenges

✓ **Graphite**

- **Naked**
- **Bolted**
- **Between inner vessel and outer vessel**
- **Many shapes and sizes**
- **High radiation field**
- **Wigner energy**
- **Possible D2O leakage**
- **No container**
- **No storage**
- **No disposal facility**





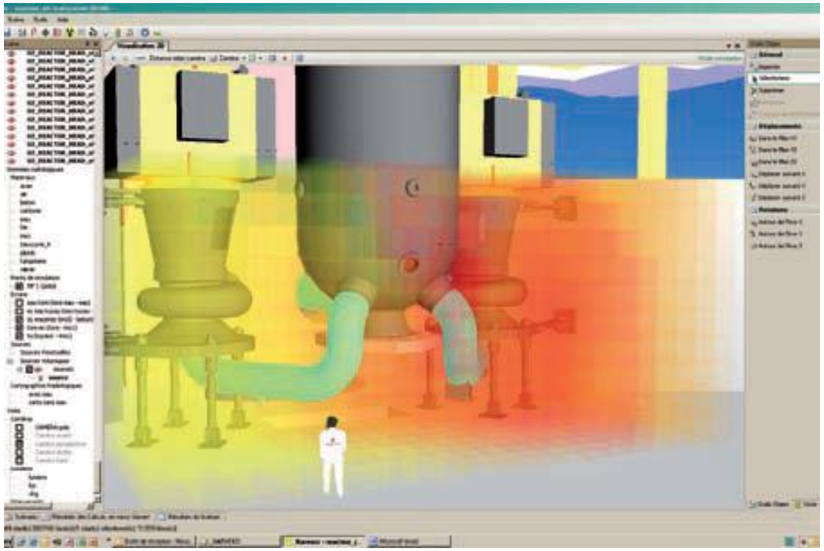
3. Challenges

✓ **Miscellaneous**

- **Equipment and software**
- **Regulations and standards**

e.g., Criteria of restricted release for a nuclear facility at a multi-facility site

- **Experience**



Part 2, Decommissioning activities at CIAE

1. Decommissioning of Nuclear Facilities

2. Decommissioning of SD MNSR

1.Decommissioning of Nuclear Facilities

- Facilities decommissioned
  a) Shandong Miniature Neutron Source Reactor (MNSR)
  b) Underground pipelines of ILW liquid
  c) Radio-Source Pool
- Facilities to be Decommissioned
  a) Heavy Water Research Reactor (HWRR)
  b) Storage facility of LLW liquid
  c) Treatment facility of ILW liquid
  d) Contaminated laundry

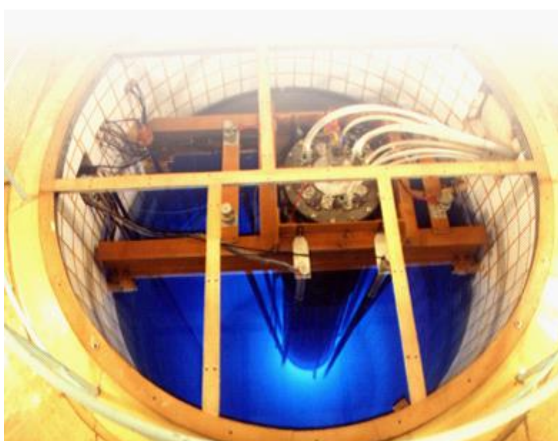
2. Decommissioning of SD MNSR

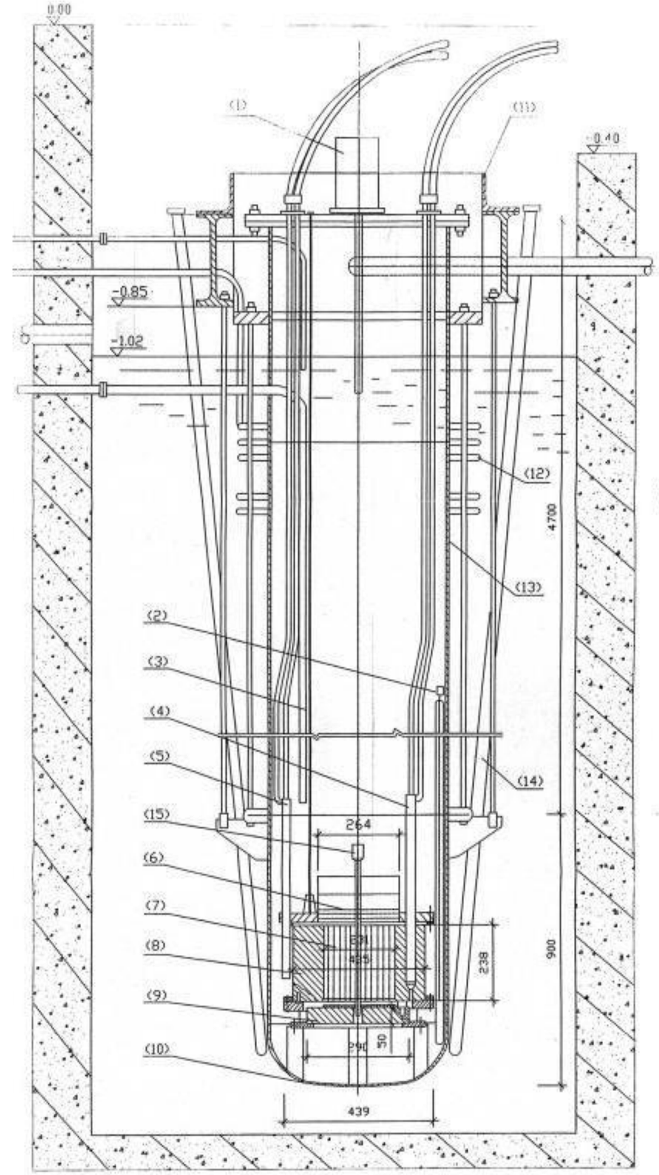
- SD MNSR was shutdown in March 2008.
- In September 2009, the core was defuelled and fuel bundle was sent back to and stored at CIAE.
- In December 2010, MEP and NNSA approved the decommissioning project.
- From December 2010 to March 2011, SD MNSR was dismantled, decontaminated and released.
- Until to December 2011, the environmental survey was finished and the results showed the site arrived the level of release without restrict.
- After the final survey, MEP approved the site to be released without restrict in April 2012 .

2. Decommissioning of SD MNSR

Constructed in 1989.

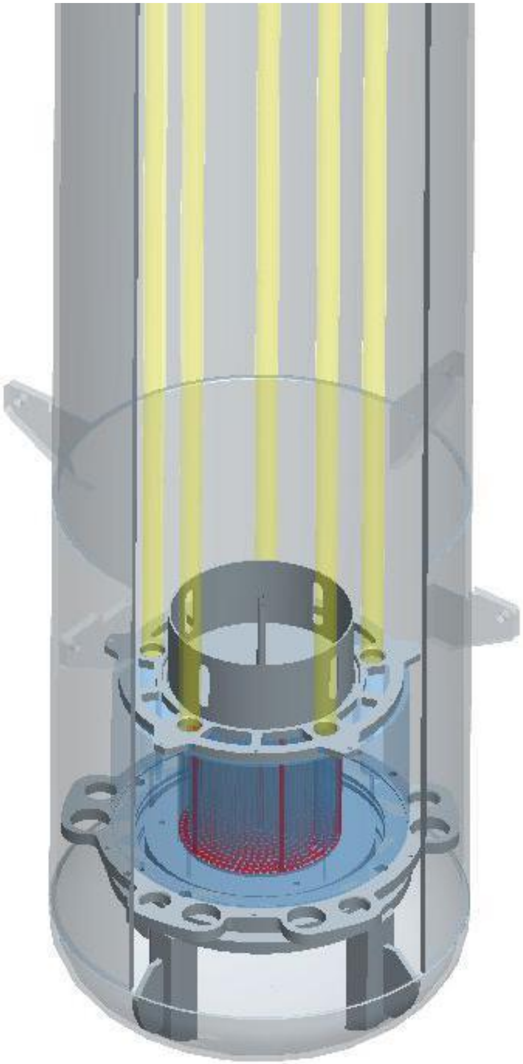
- Fuel: Uranium aluminum alloy
- Reflector: Beryllium metal
- Coolant and Moderator: H_2O
- Structure Type: Tank - pool
- Thermal Power: 30kW





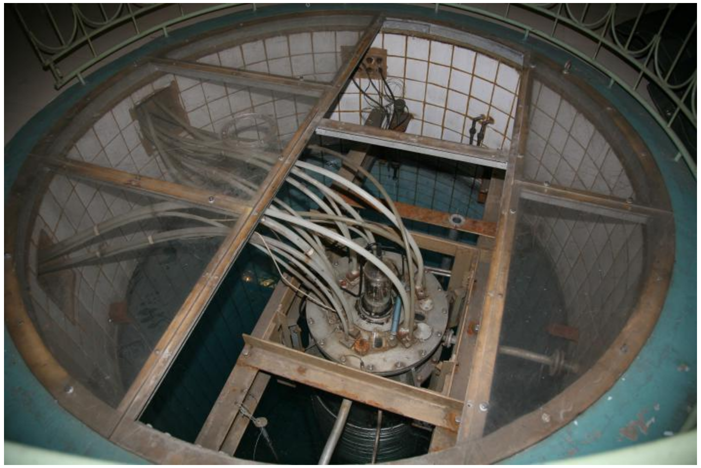
2. Decommissioning of SD MNSR

- Core cylinder
  - cylinder-shaped: Aluminum
  - Height： 5.6m
  - Inner diameter： 0.6m
  - Outer diameter： 0.62m
  - Thickness： 0.01m
  - Weight： ~0.35t



2. Decommissioning of SD MNSR

- Pool
  - Diameter: 2.7m
  - Depth: 6.5m
  - Inner wall and bottom: ceramic tile, reinforced concrete



2. Decommissioning of SD MNSR

- Objective
  - Unrestricted Release
- Scope
  - Core
  - Pool
  - Ventilation system
  - Pit of Waste
  - Waste water
  - Auxiliary systems
  - Reactor building

2. Decommissioning of SD MNSR

- Steps of SD MNSR Decommissioning
  - Modification of entrance to the reactor building
  - Radiological survey
  - Develop decommissioning plan
  - Dismantle and decontamination
  - Waste management
  - Final survey

2. Decommissioning of SD MNSR

Dissection of upper cylinder

Hoisting lower cylinder to container after pool water discharge

Part 3, Waste management activities at CIAE

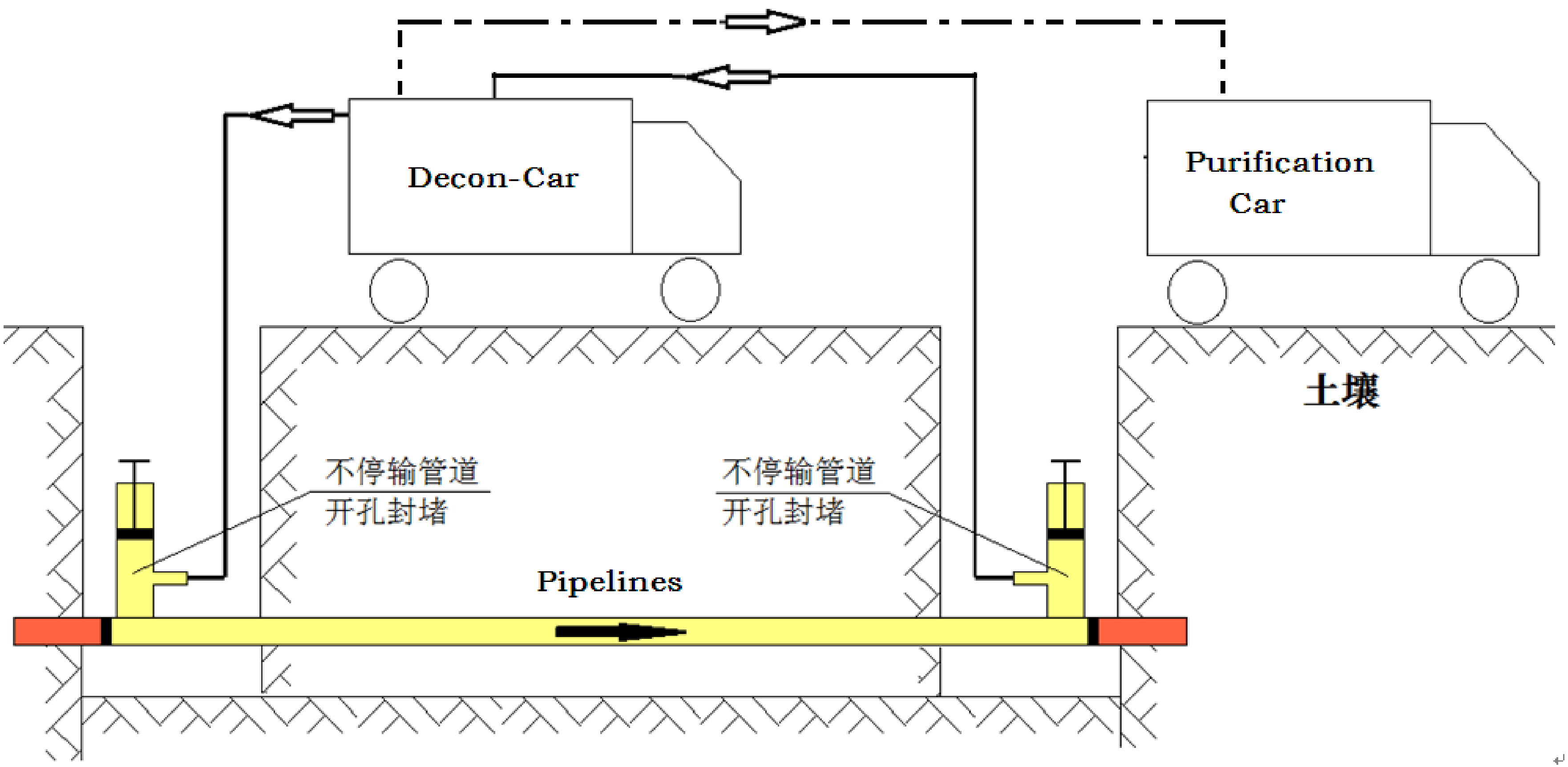
1. R&D on Decontamination

2. R&D on Waste Treatment

3. R&D on Waste Disposal

1. R&D on Decontamination

(1) Mobile Decontamination Units

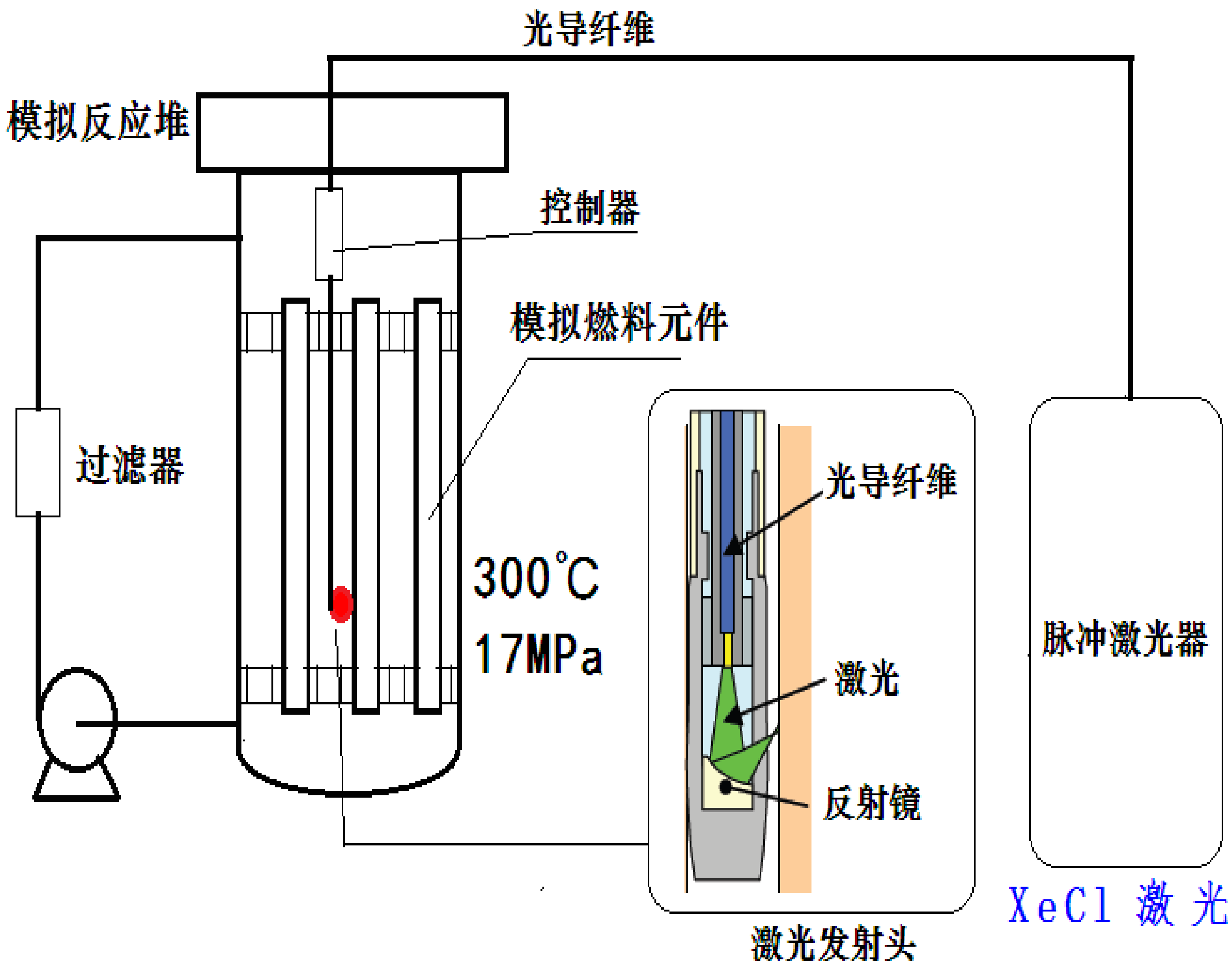


1. R&D on Decontamination

(1) Mobile Decontamination Units

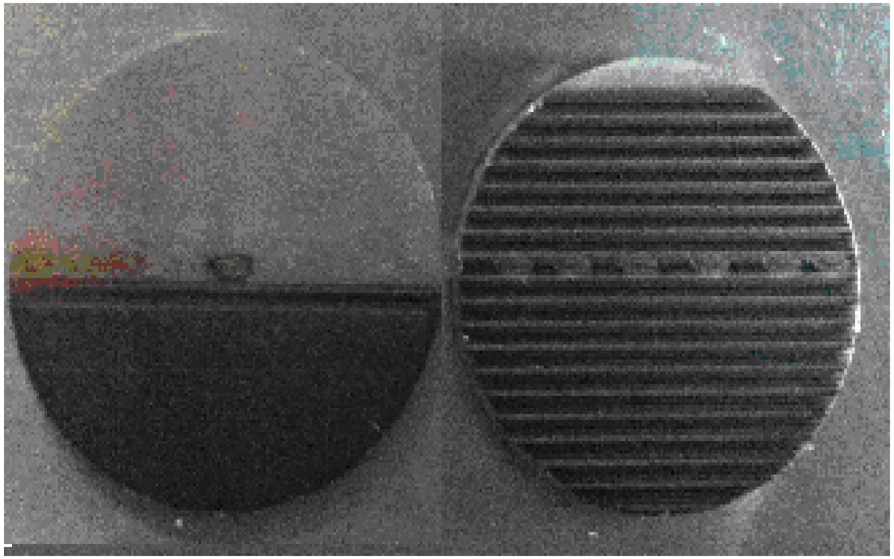
1. R&D on Decontamination

(2) Laser Decontamination



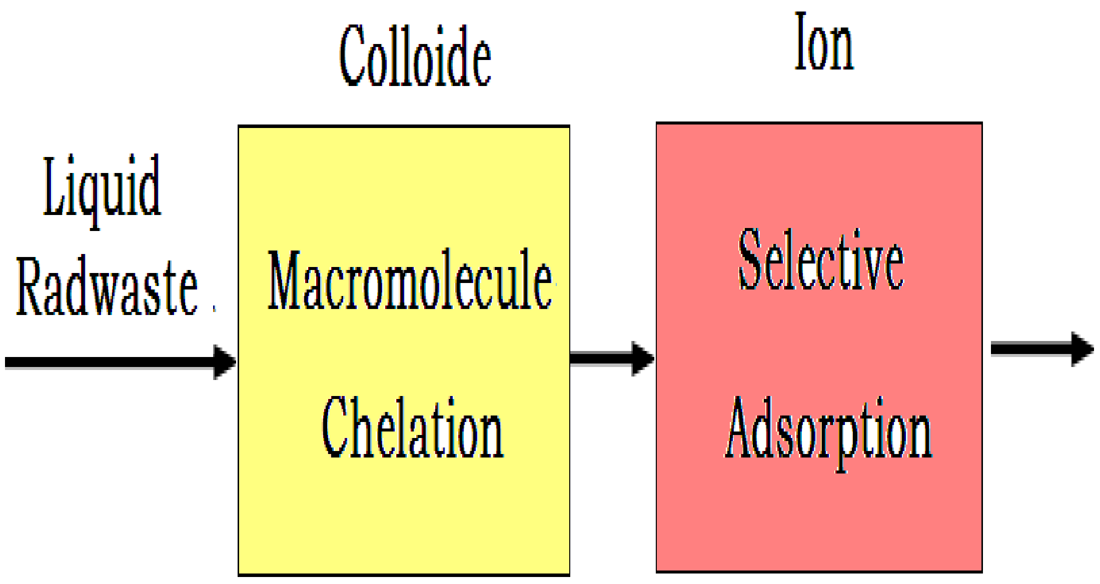
1. R&D on Decontamination

(2) Laser Decontamination

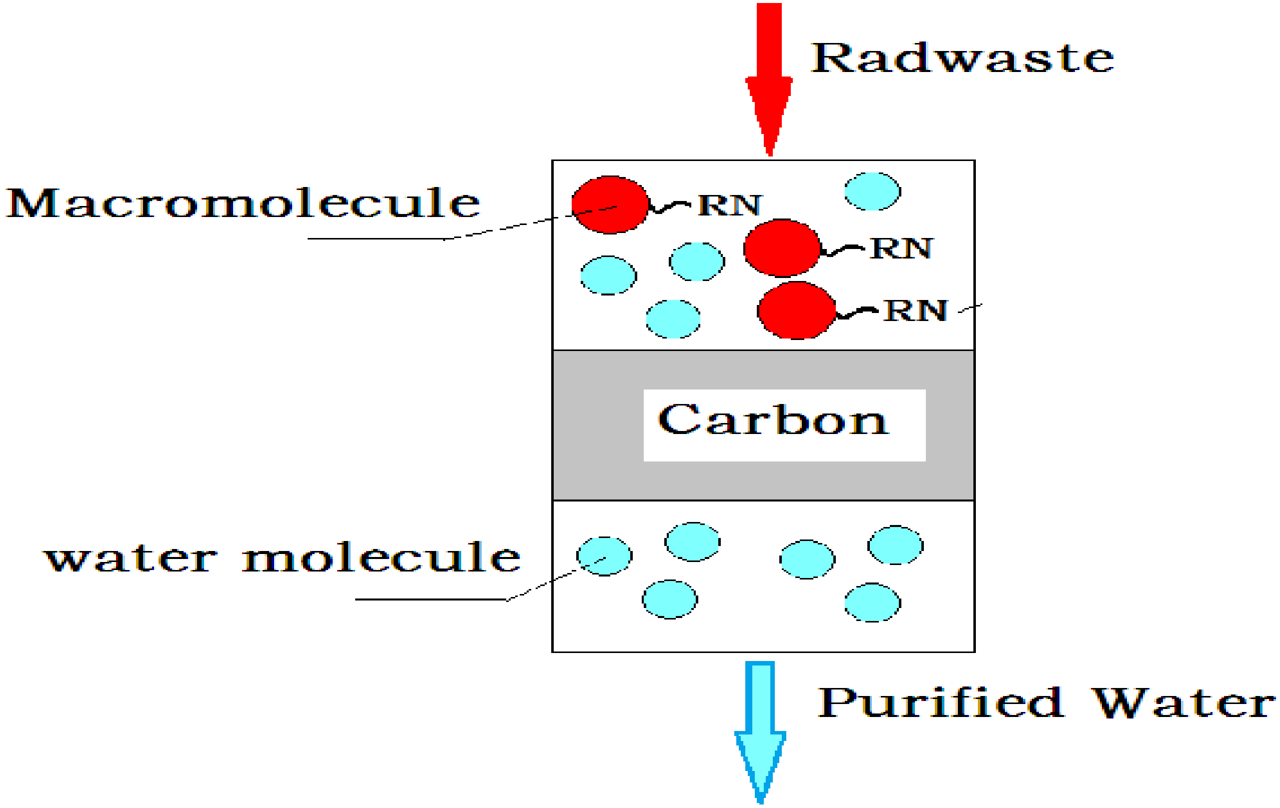


2. R&D on Waste Treatment

(1) Chelation and Sorption for Purification of LLW Liquid

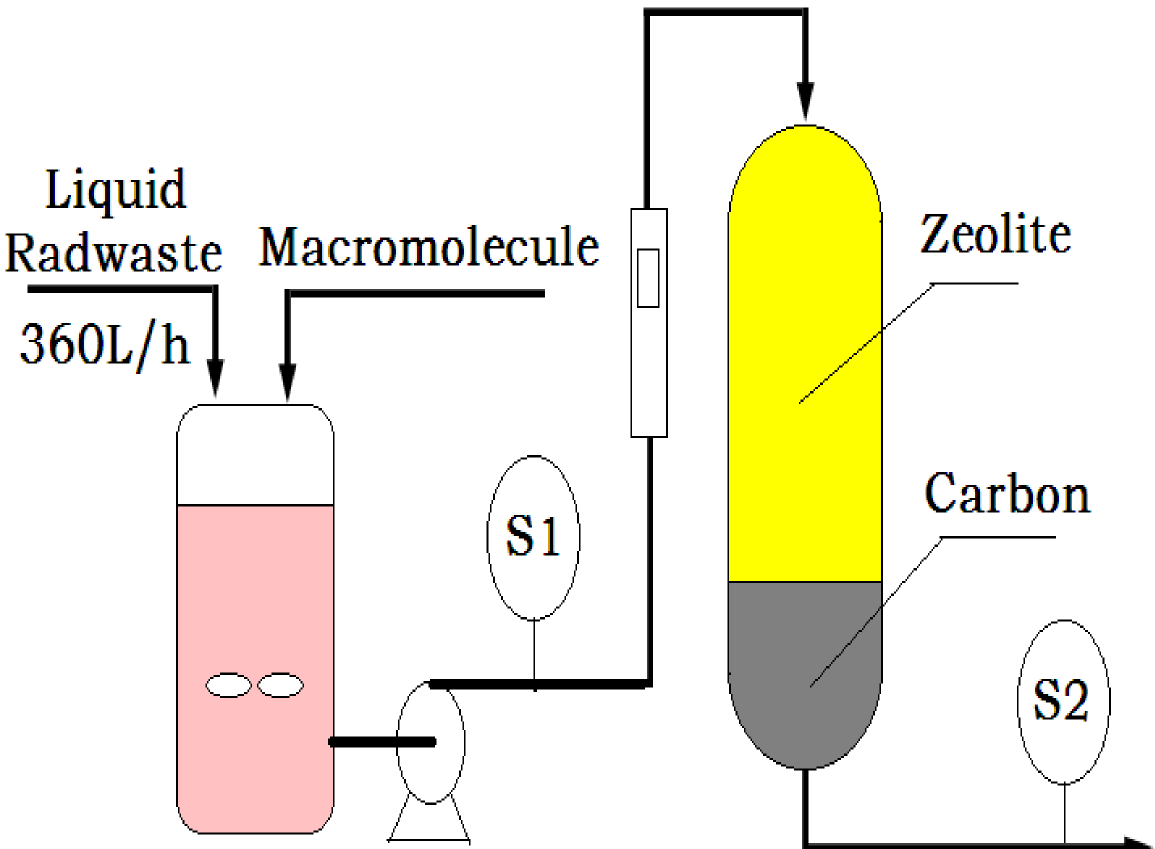


(1) Chelation and Sorption for Purification of LLW Liquid



2. R&D on Waste Treatment

(1) Chelation and Sorption for Purification of LLW Liquid



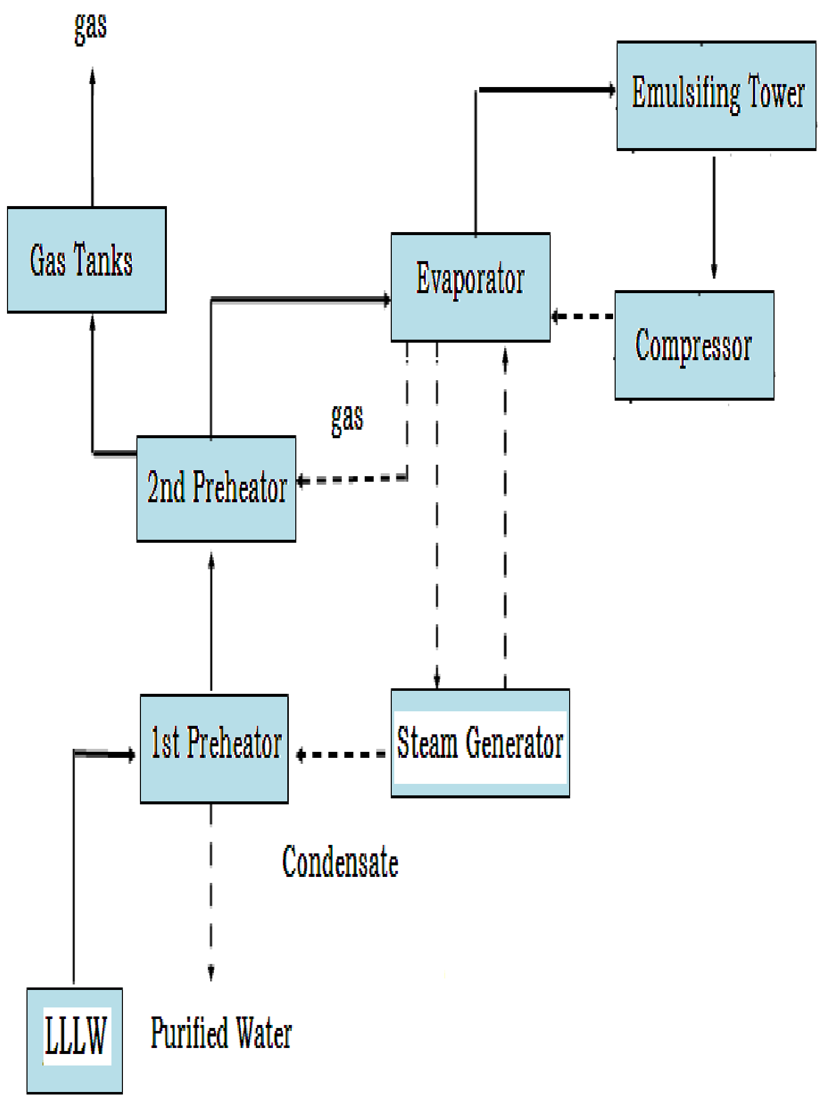
2. R&D on Waste Treatment

(1) Chelation and Sorption for Purification of LLW Liquid

- ^{60}Co:Bq/L-16Bq/L (DF>2000)
- ^{137}Cs:6Bq/L-17Bq/L (DF>1.0×10^4）
- ^{90}Sr:1Bq/L (DF>1.0×10^3）
- Volume Reduction Factor:1600

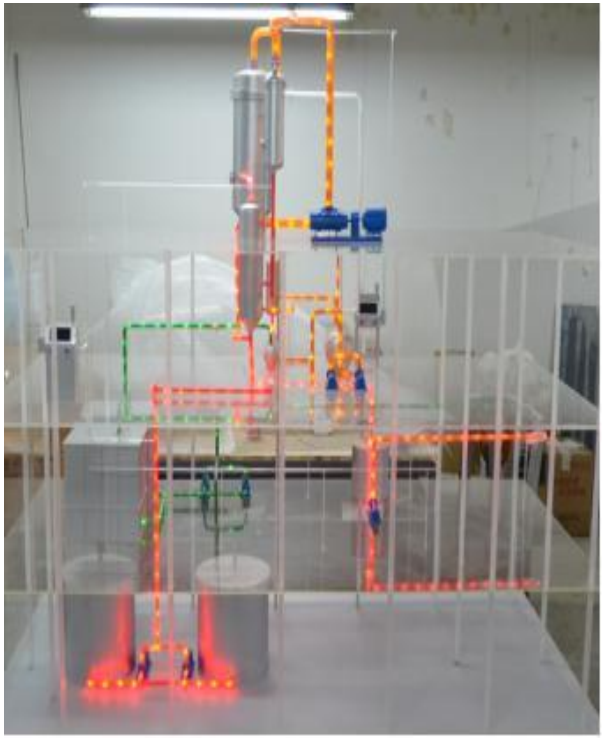
2. R&D on Waste Treatment

(2)Heat-Pump Techniques for Evaporation of LLW Liquid

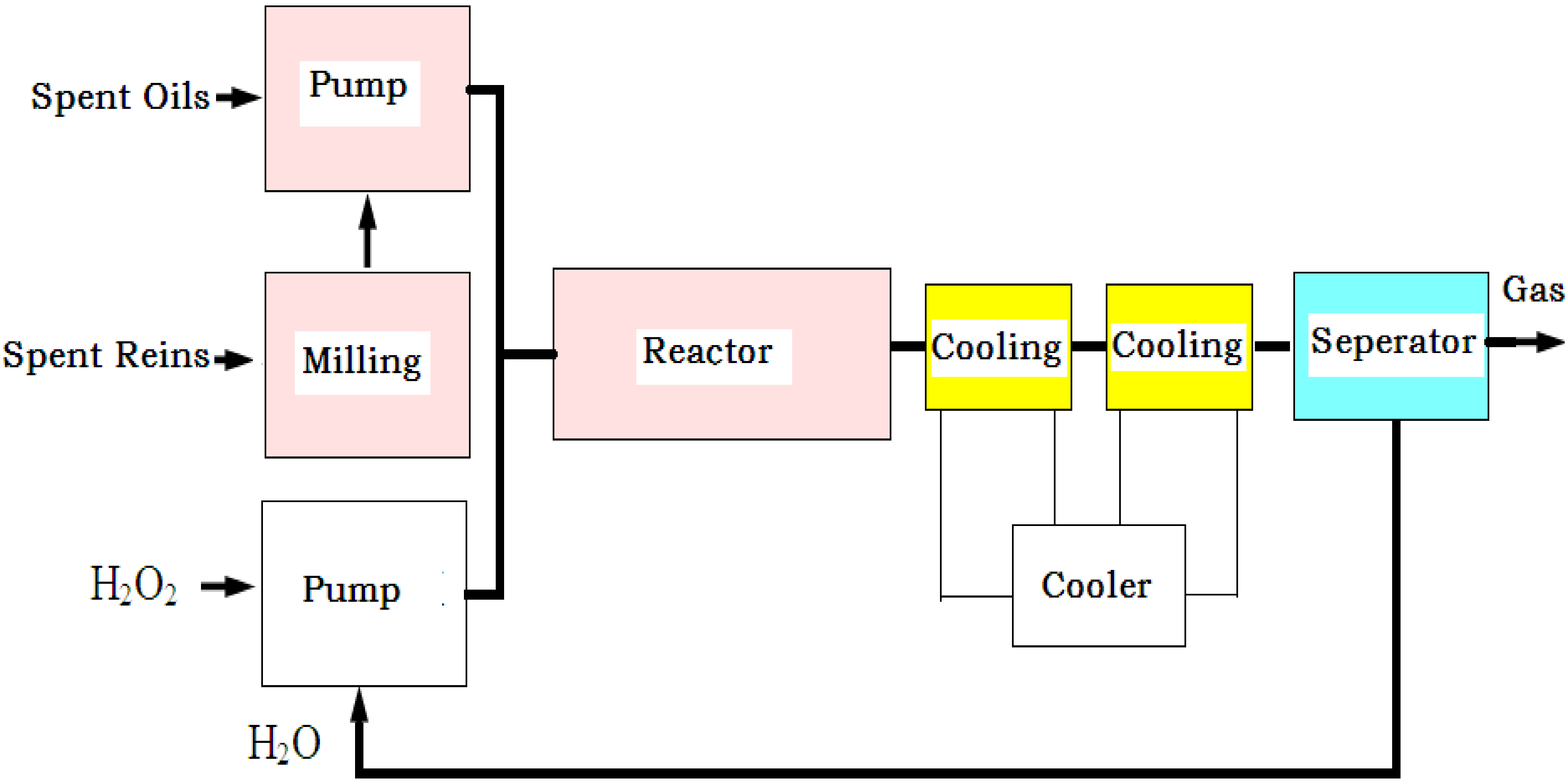


(2)Heat-Pump Techniques for Evaporation of LLW Liquid

- Capacity: $1m^3/h$
- Consecutive Period: 92days
- Total LLW: $1926m^3$
- DF: 2.46×10^5
- Energy Saving: 87.5%-91.7%



(3) Supercritical Water Oxidation of Organics



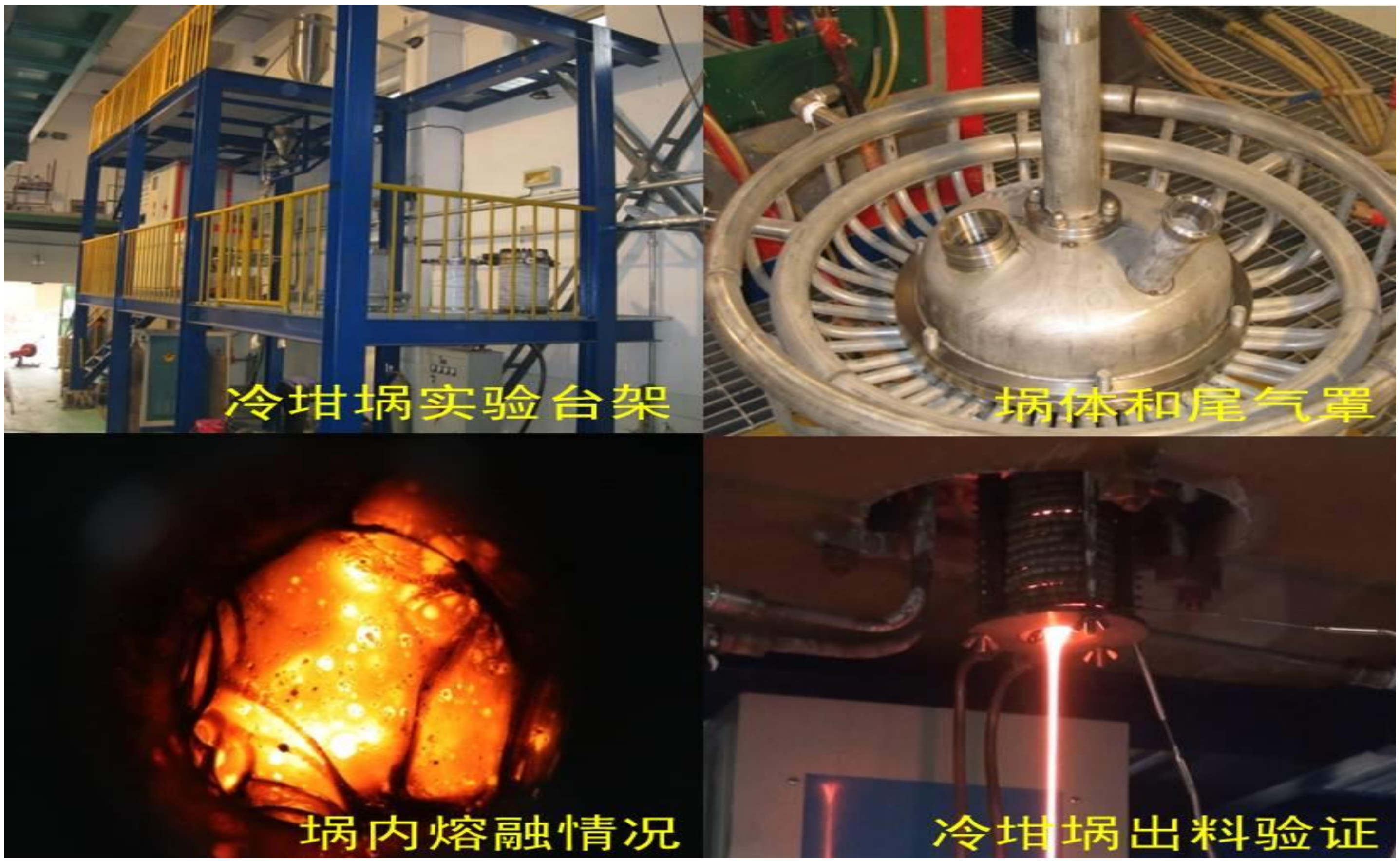
2. R&D on Waste Treatment

(3) Supercritical Water Oxidation of Organics

2. R&D on Waste Treatment

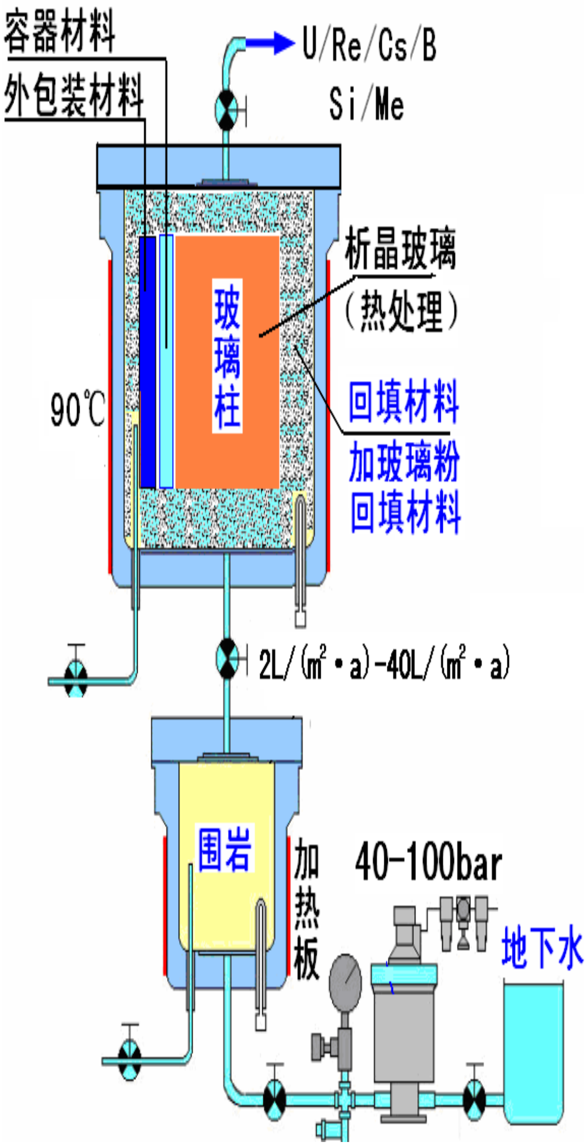
(4) Self-Sustainable Propagating High Temperature Synthesis for Graphite

(5) Cold crucible melter for vitrification of HLW liquid



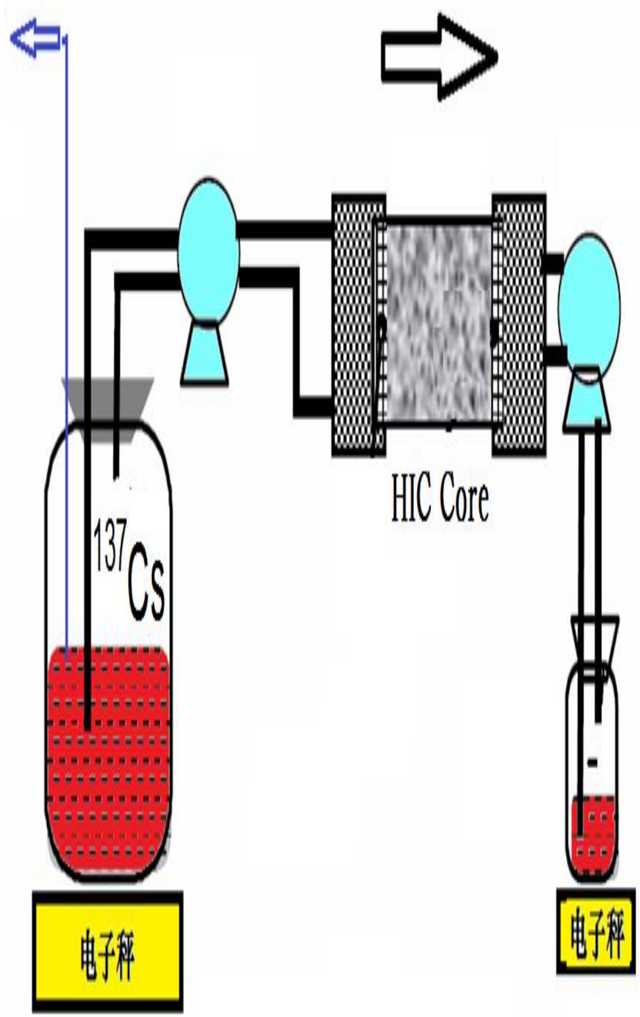
3. R&D on Waste Disposal

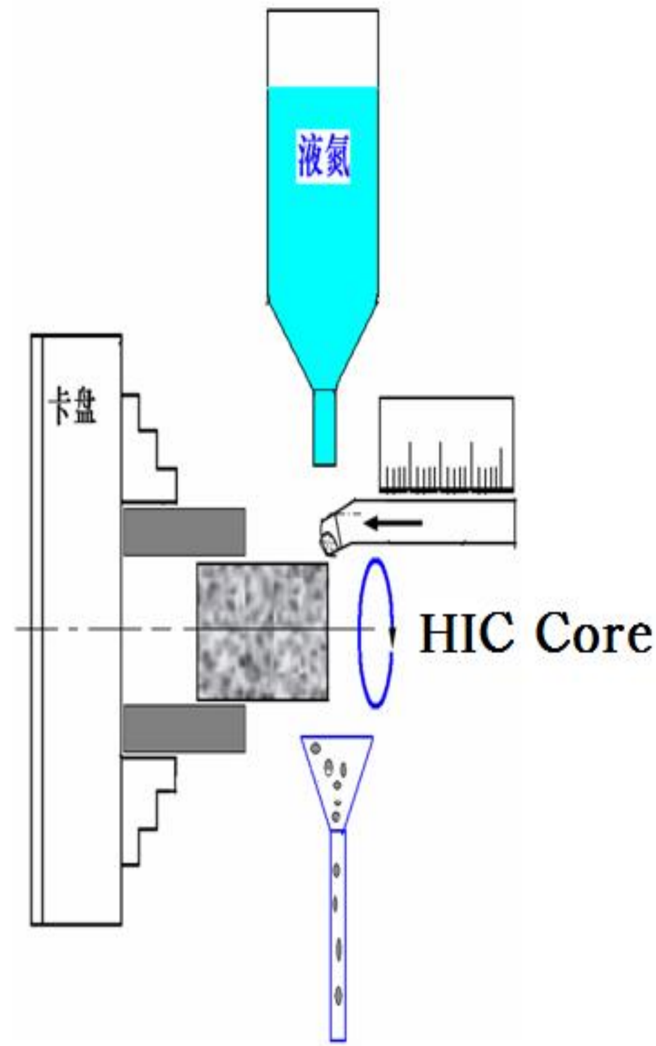
(1) Source-Term of HLW Glass



(2) Cs Diffusion in HIC Material

$De(Cs) = (3.7 \pm 3.4) 10^{-5} cm^2/d$





(3) Migration of Radionuclide

Thank You for Your Attention