The Researches of ADS and the Sustainable Development of the Nuclear Energy

Haihong Xia, Zhixiang Zhao
China Institute of Atomic Energy
P.O. Box 275(80), Beijing 102413, China
e-mail: xiahh@ciae.ac.cn
Contents

- Introduction
- China ADS Study in Phase 1
- China ADS Study in Phase 2
- Consideration in near future
- Summary
Need for Energy Source in China Will be 4 billion tons Standard Coal in 2050
Need for Electricity will be 1200 GWe, 20% NP
Nuclear Waste Accumulated up to 2050 in China

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity, GW</td>
<td>6</td>
<td>20</td>
<td>40</td>
<td>(240)</td>
</tr>
<tr>
<td>Spent fuel, t</td>
<td>7200</td>
<td>[&gt;50000]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MA, t</td>
<td>4</td>
<td>[&gt;30]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLFP, t</td>
<td>17</td>
<td>[&gt;120]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Introduction:
ADS- A Good Candidate

- The conceptual study of ADS had lasted for about five years and ended in 1999 in China.
- From 2000 a five years R&D program has been launched supported under National Basic Research Program, 973.
- After 5 years hard work, China ADS Project passed the national review successfully at the end of October, 2005.
- In January, 2009, ADS won 2nd class National Science and Technology Progress Prize.
China ADS Study in Phase 1
System Optimization
Performance Assessment of Different Blankets
Technical Design of Verification Facility

Reactor Physics and Technology
Reactor Physics Theory
Experiments on Sub-Critical Assembly with External Source
Thermo-Hydraulic Simulation

Accelerator Physics and Technology
High Current ECR Source
RFQ Injector
Accelerating Structure for Different $\beta$’s
HPPA Physics

Nuclear and Material Data Base
Spallation Neutron Source
Nuclear Data
Radiation Damage Simulation Material Compatibility
RFQ
- Reflector zone thickness ≥ 20cm
  - material: polyethylene
- Shielding zone thickness = 20cm
  - material: polyethylene with boron
- Outer shell material: stainless steel
  - thickness = 10mm
  - diameter: 1600mm
  - length: 1800mm
The Venus 1 coupled with 300 kV pulsed neutron generator
China ADS Study in Phase 2
# Neutronics and thermal-hydraulics technology research of ADS – Venus 2

<table>
<thead>
<tr>
<th></th>
<th>Spent fuel of CARR, U3Si2-Al, 149.3kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Keff</strong></td>
<td>0.982</td>
</tr>
<tr>
<td><strong>Spallation Target</strong></td>
<td>Solid W</td>
</tr>
<tr>
<td><strong>Energy of Proton Beam</strong></td>
<td>100MeV</td>
</tr>
<tr>
<td><strong>Yield of spallation neutron</strong></td>
<td>0.3 n/p</td>
</tr>
<tr>
<td><strong>Beam Intensity</strong></td>
<td>0.3 mA</td>
</tr>
<tr>
<td><strong>Beam Power</strong></td>
<td>30 kW</td>
</tr>
<tr>
<td><strong>Thermal Power of the Core</strong></td>
<td>200kW</td>
</tr>
</tbody>
</table>
### Primary Parameters for Our LBE Loop

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Temperature</td>
<td>550 °C</td>
</tr>
<tr>
<td>Maximum Flux</td>
<td>6 m³/h, (velocity 3 m/s)</td>
</tr>
<tr>
<td>Pressure</td>
<td>0.3 MPa</td>
</tr>
<tr>
<td>Oxygen Control</td>
<td>Ar + 5% H₂/H₂O</td>
</tr>
<tr>
<td>LBE capacity</td>
<td>100～150 l</td>
</tr>
<tr>
<td>Height of Loop</td>
<td>5 m</td>
</tr>
<tr>
<td>Experimental Segment</td>
<td>2</td>
</tr>
<tr>
<td>Height of Segment</td>
<td>1.5～2 m</td>
</tr>
<tr>
<td>Velocity of Flux</td>
<td>1 m/s</td>
</tr>
<tr>
<td>Temperature Difference</td>
<td>100 °C</td>
</tr>
</tbody>
</table>
Neutronics Research of ADS Sub-critical Reactor System

• Analysis Primary experimental Results

• More measurements
Primary Results

Layers of Fuel loading

related counting rate

Layers of Fuel loading

related counting rate

Related to fuel loading levels and related counting rates for different detectors.
Perfection and Benchmark of Nuclear Data Library for ADS

Neutron induced reaction data for $^{28,29,30}\text{Si}$, Cr, Fe, Ni, Cu, $^{93}\text{Nb}$, $^{97}\text{Mo}$, $^{129}\text{I}$, $^{125}\text{Sb}$, W, $^{209}\text{Bi}$, Pb, Th, U, Pu etc.

Proton induced reaction data for $^{27}\text{Al}$, $^{30}\text{Si}$, $^{54,65}\text{Fe}$, $^{181}\text{Ta}$, Hg, $^{208}\text{Pb}$, $^{209}\text{Bi}$ etc.
The (n, 2n) and (n, 3n) cross sections for $n^+^{238}$U reaction
Results of calculations for the uranium critical benchmarks with different libraries

ICSBEP Benchmarks C/E-1 [pcm] (dependence on source library)
Key Technology Research on Proton Beam Loss Control

- Improvement of cooling system etc.
- Duty Factor: From 7% to 13.2%.
- Hydrogen beam extracted from the ECR source: From 65 mA to 89mA.
Key Technology Research on Proton Beam Loss Control- ECR source
Research of ADS related materials
SCK: 9Cr2WVTa, 316LN and 12CrWTi in Pb-Bi pool

9Cr2WVTa  12CrWTi  316LN

Before

after

450°C, Pb-Bi, 3000h, Oxygen 5 × 10⁻⁷ (wt %)
Brasimone: 12CrWTi in Pb loop
316LN in Pb-Bi loop

CHEOPE-III loop, \( T = 500^\circ \text{C} \), Oxygen \( 10^{-6} \) wt\%, Pb velocity 1m/sec

LECOR Pb-Bi loop, \( T = 450^\circ \text{C} \), Oxygen \( 7.3 \times 10^{-8} \) wt\%, Pb-Bi velocity 1m/sec
A three-electrode measure system has been set up. The molten salt electrolytic cell is made up of a quartz chamber and a water-cooled lid sealed by flange structure.
Electrochemical processes of Lanthanum chloride and Uranium chloride in Molten LiCl-KCl

• The electrochemical redox process of La(III) in the molten LiCl-KCl eutectic in the temperature range 683-773K on molybdenum electrode was studied by cyclic voltammetry and chronopotentiometry. The reduction of La(III) in the LiCl-KCl mixture occurs in a single step with an exchange of three electrons, the reversibility of this process was studied. LnDLa(III)=7.742-1.441×10^4/T and were obtained.

• The reduction of U(III) occurs in a single step with an exchange of three electrons. It was determined that at a sweep rate of ≤0.2Vs⁻¹, the electro reduction of U(III) to U was reversible, but at >0.2Vs⁻¹, mixed diffusion and electron-transfer control was observed. The formal potential of U(III)/U was determined and the reduction process of U(IV) to U(III) was also studied.
The dendritic uranium deposits were prepared by electrolysis in the molten LiCl-KCl eutectic, and the morphology of the deposits and cross-section of the 304 stainless steel cathode were investigated using SEM.
Consideration in near future
Consideration in near future

A moderate style multi-purpose verification system is under consideration. In the conceptual study, we consider:

- Low energy accelerator
- MW swimming pool light water sub-critical reactor
Development step

- Develop ADS step by step
- Depend on budget
- Cooperation with other project
  CSNS, BRIF…
Step by Step

1st, R&D of key technology:
- ECR ion source
- RFQ
- Super conducting cavity etc

2nd, Integral Test:
- 150MeV, 50mA, 6%

3rd, CW:
- 300MeV, Sub-critical reactor

4th, 1GeV, ADS Demo
Artist View of the CSNS

25Hz
1.6GeV
100kW
$2.5 \times 10^{16}/\text{cm}^2/\text{s}$
2011 Year
Tandem Upgrading Project
Beijing Radioactive beam Facility (BRIIF)
100 MeV Cyclotron
SUMMARY

For long term and sustainable nuclear energy development, ADS is an option in fuel circulation. ADS has been started to develop with a rather moderate project in China and is still in the early stage. Different options have been taken into account to develop ADS in China. ADS should be developed step by step without stop.
Thank you!