Nuclear District Heating
Warm the World, Guard the Globe

(Deep-pool Low-temperature Heating Reactor---DHR)

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• Any human activity leaves a carbon footprint.
• Massive uses of fossil fuels lead to GHG emission, global warming, and extreme weather.
• Frequent haze in recent years in China.
Chinese President Xi Jinping delivers a speech at the opening ceremony of the United Nations (UN) climate change conference in Paris, France, Nov. 30, 2015.

China has pledged to peak CO₂ emissions by 2030.

China will increase non-fossil energy sources in the total primary energy supply to around 20% by 2030.
Contribution of NPPS to GHG reduction

- Nuclear energy plays an important role in world electricity supply and contributes a lot in carbon dioxide emission reduction.
- The world’s NPPs have reduced 6 billion tons of carbon emission, equivalent to 15 million hectares afforestation.
There exists a huge demand for green energy in the market of central heat supply in China.

Nuclear provides an ideal alternative to fossil fuel heating.
Nuclear Heating

Using the heat generated by a nuclear reactor for heat supply

Overall schematic of District Heating System
CNNC has developed a Deep-pool Low-temperature Heating Reactor (DHR, Yan Long, 燕龙) on the basis of a pool type research reactor.

The prototype of DHR(Yan Long) is the swimming pool reactor (SPR IAE) located at CIAE of CNNC.
A proper core outlet TEMP is achieved by increasing the static pressure of the water layer.
<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
<th>Item</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermal power /MW</td>
<td>400</td>
<td>enrichment of equilibrium refueling</td>
<td>3.1%</td>
</tr>
<tr>
<td>cooling type</td>
<td>forced</td>
<td>refueling period /EFPD</td>
<td>450</td>
</tr>
<tr>
<td>diameter of pool /m</td>
<td>10.0</td>
<td>average discharge burnup /GWD/tU</td>
<td>~30</td>
</tr>
<tr>
<td>depth of pool /m</td>
<td>26</td>
<td>refueling number per year /assembly</td>
<td>24</td>
</tr>
<tr>
<td>height of active zone /m</td>
<td>2.15</td>
<td>temperature of pool water /℃</td>
<td>68</td>
</tr>
<tr>
<td>equivalent diameter of core /m</td>
<td>2.02</td>
<td>inlet/outlet of core /℃</td>
<td>68/98</td>
</tr>
<tr>
<td>type of assembly</td>
<td>truncated PWR</td>
<td>inlet/outlet of secondary circuit /℃</td>
<td>63.5/93.5</td>
</tr>
<tr>
<td></td>
<td>assembly(CF3-S)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>number of assemblies</td>
<td>69</td>
<td>inlet/outlet of heating loop /℃</td>
<td>60/90</td>
</tr>
<tr>
<td>form of assembly</td>
<td>$17 \times 17.25$</td>
<td>pressure of primary /MPa</td>
<td>0.6</td>
</tr>
<tr>
<td>diameter of fuel rod /mm</td>
<td>9.5</td>
<td>pressure of secondary /MPa</td>
<td>1.2</td>
</tr>
<tr>
<td>fuel loading of core /t</td>
<td>23.45</td>
<td>pressure of heating loop /MPa</td>
<td>1.8</td>
</tr>
<tr>
<td>average linear power density /kW/m</td>
<td>8.87</td>
<td>type of heat exchanger for primary circuit</td>
<td>Plate-type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and secondary circuit</td>
<td></td>
</tr>
</tbody>
</table>
3(1\textsuperscript{st}, 2\textsuperscript{nd} and 3\textsuperscript{rd}) circuits layout, 2 times heat exchange

- Setting up the 2\textsuperscript{nd} isolation circuit
- P_3 > P_2 > P_1, to ensure radioactivity will not enter heating pipe
Main Technical Features

- High safety and environment-friendly
- Multi-purpose and adaptable
- Less investment and better economy
Inherent Safety

1. 1800 tons of water

2. Underground reactor

3. No overpressure, LLOCA, ejection of control rod, failure of safety valve, etc.

4. Large negative reactivity coefficient

5. Huge steam specific volume under low pressure, self-protection of phase change
The most serious credible accident

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Accident sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SBO ATWS,FP</td>
</tr>
<tr>
<td>0~6000</td>
<td>$\rho, P, T_c, T_f$, oscillating, not beyond the limit</td>
</tr>
<tr>
<td>6000</td>
<td>Smooth change, stabilizing at 10% P</td>
</tr>
<tr>
<td>3.1E7(10d)</td>
<td>Core uncover</td>
</tr>
</tbody>
</table>

- **Nearly “zero” meltdown**

- **Automatic shutdown only relying on the negative reactivity feedback, without any intervention.**
Almost none release

Multiple means to reduce radioactive release

- DHR is equipped with four barriers, effectively isolating radioactivity
- An intermediate isolation circuit with higher pressure ensure that the coolant does not enter the heating loop.
- Equipped with a gaseous and liquid effluence collection and treatment system
No carbon emission, no emission of NOₓ, SO₂, dust, ash, etc. DHR400 can replace 320,000 tons of coal per year, equivalent to 1300 hectares afforestation.

<table>
<thead>
<tr>
<th>Heat source</th>
<th>CO₂ (tons/y)</th>
<th>SO₂ (tons/y)</th>
<th>NOₓ (tons/y)</th>
<th>Dust (tons/y)</th>
<th>Ash (tons/y)</th>
<th>Radioactivity (mSv/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>520000</td>
<td>6000</td>
<td>2000</td>
<td>3200</td>
<td>100000</td>
<td>0.013</td>
</tr>
<tr>
<td>Gas</td>
<td>260000</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td>0.005</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.005</td>
</tr>
</tbody>
</table>
Multi-purpose

- Energy application
  - District heating supply
  - Refrigeration (lithium-bromide absorption-type refrigerating machine)
  - Desalination of Sea Water (low temp. multiple effect distillation (MED))
  - Supply hot water for green-house, farming, cultivation, etc.

Non-heating season
Neutron application

- Irradiation testing for fuel assemblies and material
- Production of RIs, NTD silicon, gem, topaz, pearl, nuclear membrane, etc.
- Neutron analysis, NAA, NRG, Neutron scattering, etc.
- Medicine, BNCT, FNT, etc.
Roadmap of DHR

1\textsuperscript{st} step
Principle verification
2017-12

2\textsuperscript{nd} step
Demo Project
2020-12

3\textsuperscript{rd} step
Commercial promotion
After 2020
Demonstration Project

Demonstration site
Xudapu, Liaoning Province, China

2019-4-30 Approval

2020-4-30 Confinement completed

2021-4-30 Heating supply

2019-7-31 FCD

2021-2-31 First criticality
Remarks

- DHR is safe, environment friendly and economical.
- DHR provides an ideal alternative to coal-fired heating.
- DHR would make important contributions to CO₂ emission reduction and environment protection.
Thanks for your attention