Progress of SMR test facility in NPIC

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Contents

Nuclear Power Institute Of China

Introduction to NPIC

The Nuclear Power Institute of China belongs to China National Nuclear Corporation, is a large nuclear power scientific research base integrating the research, design, test, operation, decommissioning and mass production of nuclear power technology, and is a national strategic high-tech research and design institute.





- Our thermal engineering and safety experimental research base of reactors has **the largest number of installations**, **the largest scale and the most advanced indexes** of China
- Our experimental research and development capability is **leading in China and first-class in the world**

Contents

Introduction to Test Device（NPIC）

1.Reactor integral hydraulic test facility

Main performance Parameters

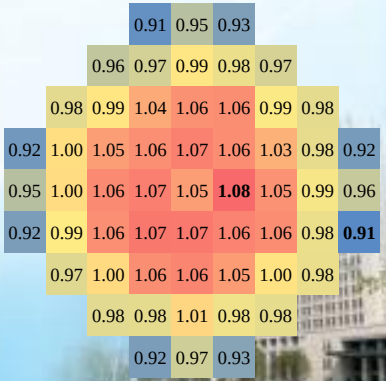
- The number of loop:4
- Main pump flow of single loop:800m^3/h
- Main pump head of single loop:120m
- Design temperature:80℃
- Design pressure:1.6MPa

Function

- Simulation test research of reactor integral hydraulic

Relevant tests

- CAP1400,China Engineering Test Reactor and ACP100 reactor integral hydraulic simulation test has been completed on the facility.



Introduction to Test Device（NPIC）

2.Control Rod Driving Line Test Facility

Main performance Parameters

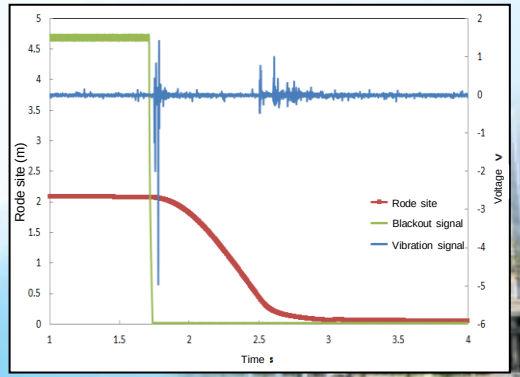
- Design Pressure: 17.2MPa
- Design Temperature: 350℃
- Rated Flow: 800m³/h

Function

- CRDL thermal state tests
- Fuel assembly erosion corrosion Test

Relevant tests

- Control Rod Driving Line Test Facility
- The CRDL thermal state tests and fuel assembly erosion corrosion test for ACP100 has been carried out on this facility.



Introduction to Test Device（NPIC）

3.Large Scale Thermal Hydraulics Test Facility

Main performance Parameters

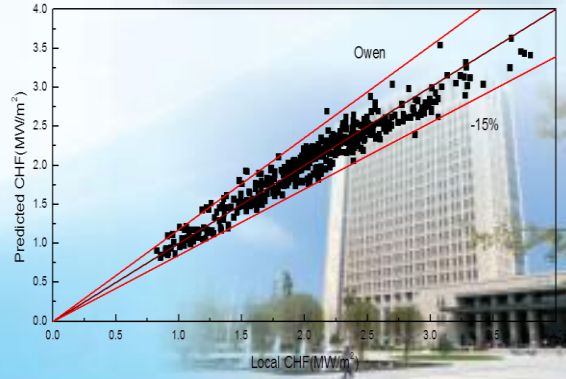
- Design pressure: 20MPa
- Design temperature: 370℃
- Max pressure: 17.5MPa
- Max temperature of Primary Pump: 300℃
- Power of preheater: 800kW
- Max flow rate of Primary Pump: 500 t/h
- Max flow rate of primary loop: 220 t/h
- Max flow rate of test section: 70t/h

Function

- Mixture Coefficient of Fuel assembly test
- Critical heat flux(CHF) of Fuel assembly test
- Thermal Hydraulics Performance test

Relevant tests

- Critical heat flux(CHF) of ACP100 Fuel assembly has been carried out in this facility.



Introduction to Test Device（NPIC）

4.ACP100 SMR passive safety system test facility

Main performance Parameters

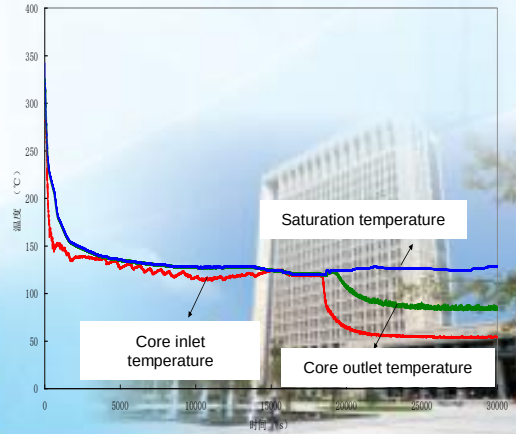
- Design pressure:17.5MPa
- Design temperature:350℃

Function

- DBA simulation test for SMR
- Comprehensive performance test for SMR safety systems

Relevant tests

- ACP100 SMR LOCA, SBO and passive safety system equipment characteristic has been carried out in this facility.



Introduction to Test Device（NPIC）

5.Thermal hydraulic test facility of supercritical water

Main performance Parameters

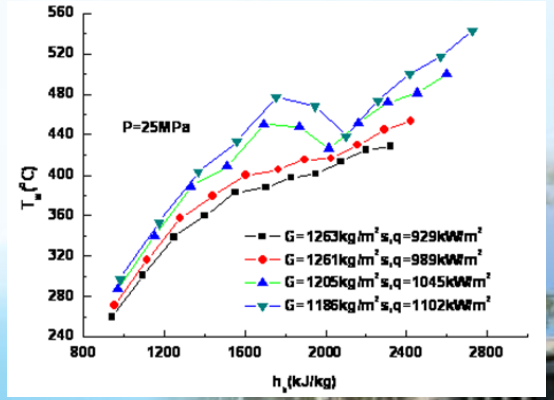
- Test pressure：30MPa
- Test flow rate：6t/h
- Test temperature: 500℃

Function

- Flowing and heat transfer test of single tube
- Thermal hydraulic test of bundle
- Throttling coefficient test
- Flowing instability test

Relevant tests

- Various thermal hydraulic tests of Several OTSG types had been carried out in this facility, including steady and transient state thermal hydraulic performance test, flowing instability test of small scale bundle of OTSG.



Introduction to Test Device（NPIC）

6.Multi-point excitation test device

Main performance Parameters

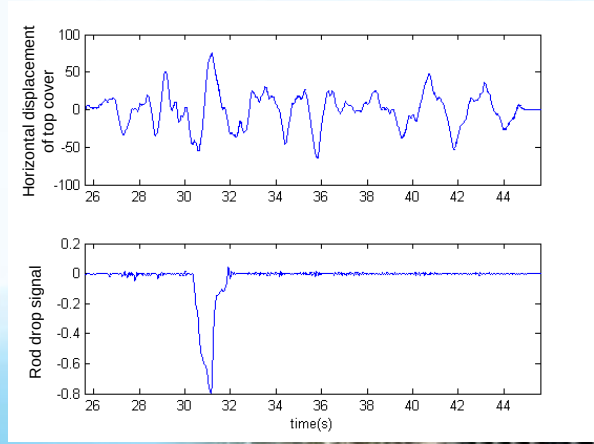
- Number of hydraulic exciters: 6
- Maximum excitation force: 63kN
- Frequency of hydraulic exciters: 0.1-80 Hz
- Maximum displacement: ±125 mm

Function

- Seismic Qualification Test for Rod Drive Line

Relevant tests

- Seismic qualification tests for Control Rod Drive Line of Qinshan haseII, CEFR, AP1000, CAP1000, CAP1400, ACP1000, ACP100 and CFR600 have been carried out.



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Relevant tests (NPIC)

◆ ACP100 SMR passive safety system test facility

❑ Short-term performance study of passive core cooling system

Study and verify the core cooling and flooding characteristics under different break locations and different break sizes LOCA working conditions.

❑ Experimental study on long-term recirculation after water loss

Study and verify whether the current design can take away core waste when the reactor pressure vessel and containment pressure balance after the water loss accident enters the long-term recirculation stage.

❑ Experimental study of full-field power failure accident

Simulate the transient process of the whole plant power failure. Study and verify the natural circulation capacity of passive residual heat removal system, the long-term heat transfer capacity of passive residual heat discharge cooler and refueling water tank in the containment under the accident.

- ACP100 passive emergency reactor core cooling comprehensive test research project has completed 38 groups of test conditions

1. Steady condition—6 groups
2. Short-term performance study of passive core cooling system condition—8 groups
3. Long-term recirculation after water loss condition—14 groups
4. Full-field power failure accident condition—10 groups

Relevant tests (NPIC)

Simulation scale

The simulation scale of the test devices

Number	Simulation quantity	Simulation scale	Number	Simulation quantity	Simulation scale
1	Pressure	1：1	8	Water capacity	1：37.62
2	Temperature	1：1	9	Power	1：37.62
3	Time	1：1	10	Heat exchange area	1：37.62
4	Length	1：1	11	Friction number	1：1
5	Cold and hot core height difference	1：1	12	Mass flow rate	1：37.62
6	Flow diameter	1：6.13	13	Pressure drop	1：1
7	Core flow area	1：37.62	14	Fracture area	1：37.62

Relevant tests (NPIC)

System flow

Primary system:
Reactor simulators and pressure safety systems

Passive emergency cooling system:
High pressure safety injection system, low head safety injection system

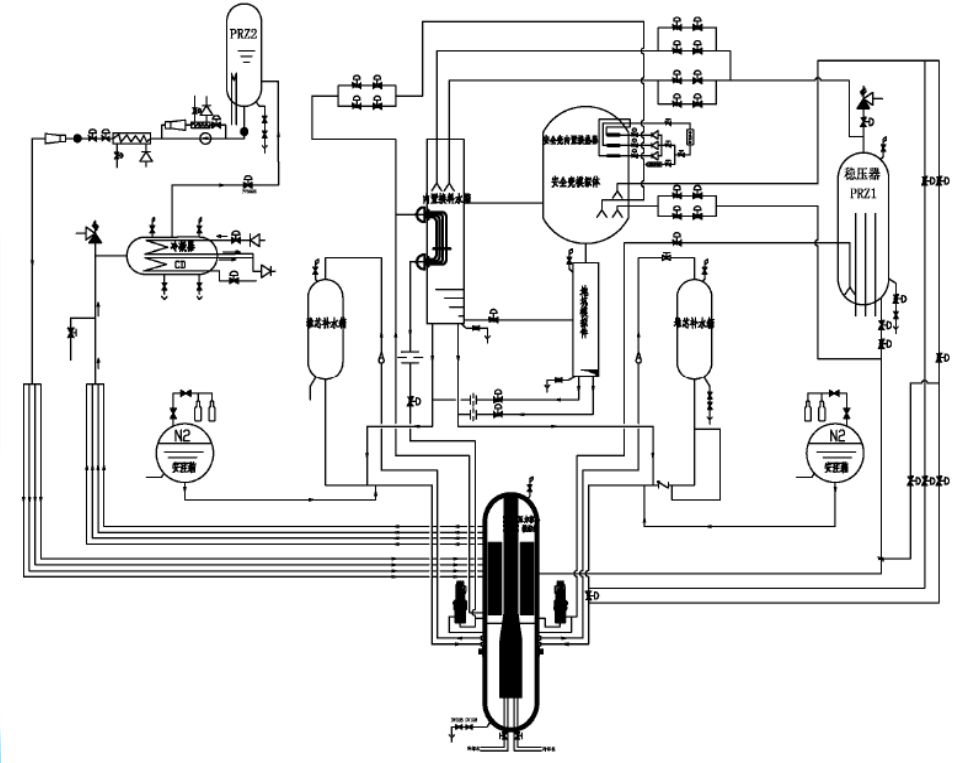
Long-term circulation cooling system

Secondary circuit system

Passive coarray system

Fracture simulation system

Automatic pressure relief system

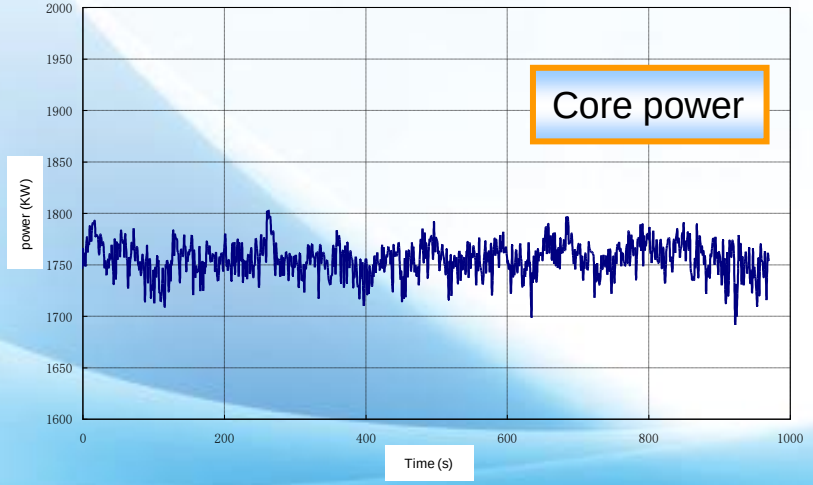


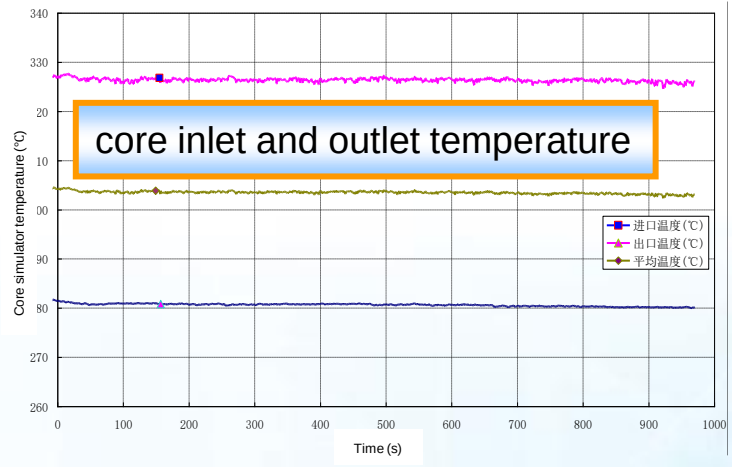
Relevant tests (NPIC)

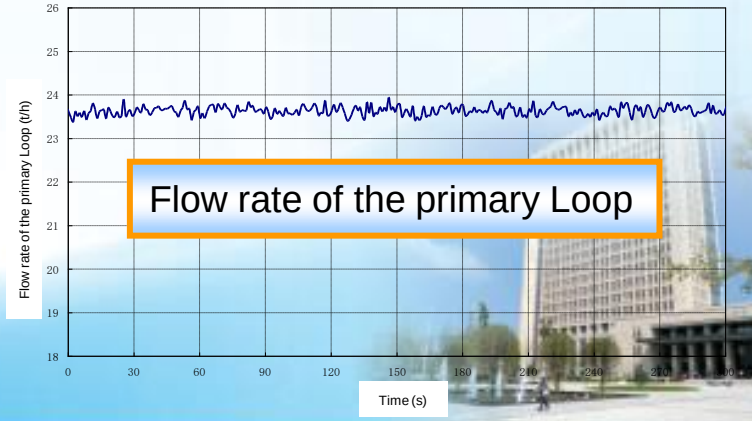
Experiment results

- Steady-state experiment

Average core inlet and outlet temperature 304.3℃，20%FP



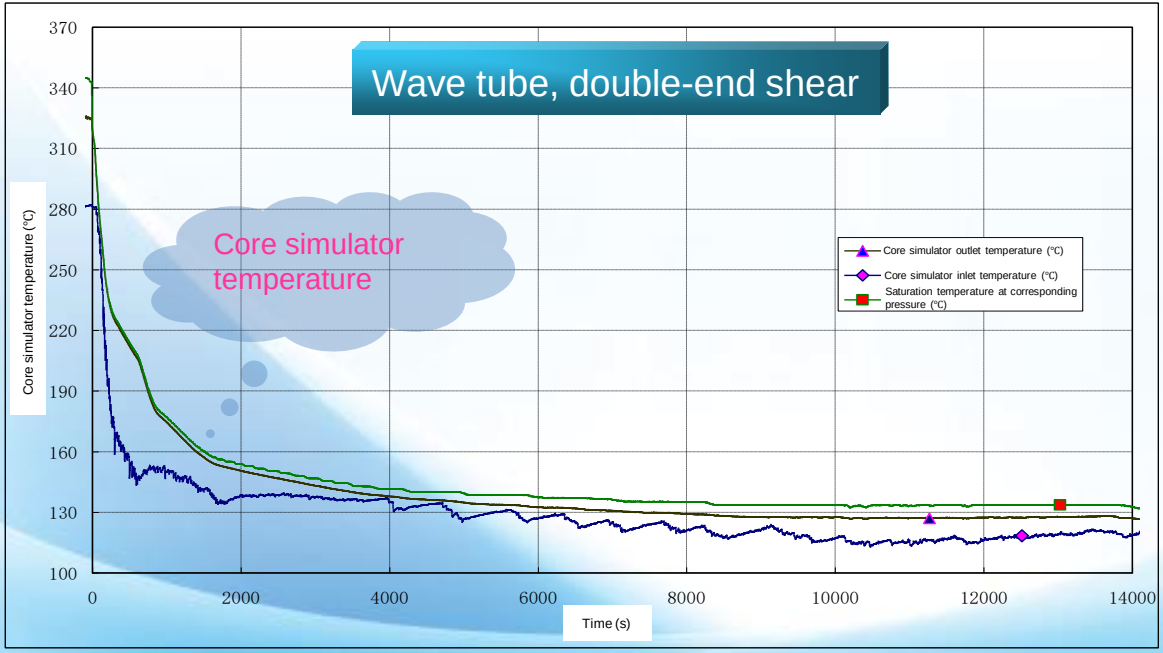




Relevant tests (NPIC)

Experiment results

- Experiment of short-term performance study of passive core cooling system

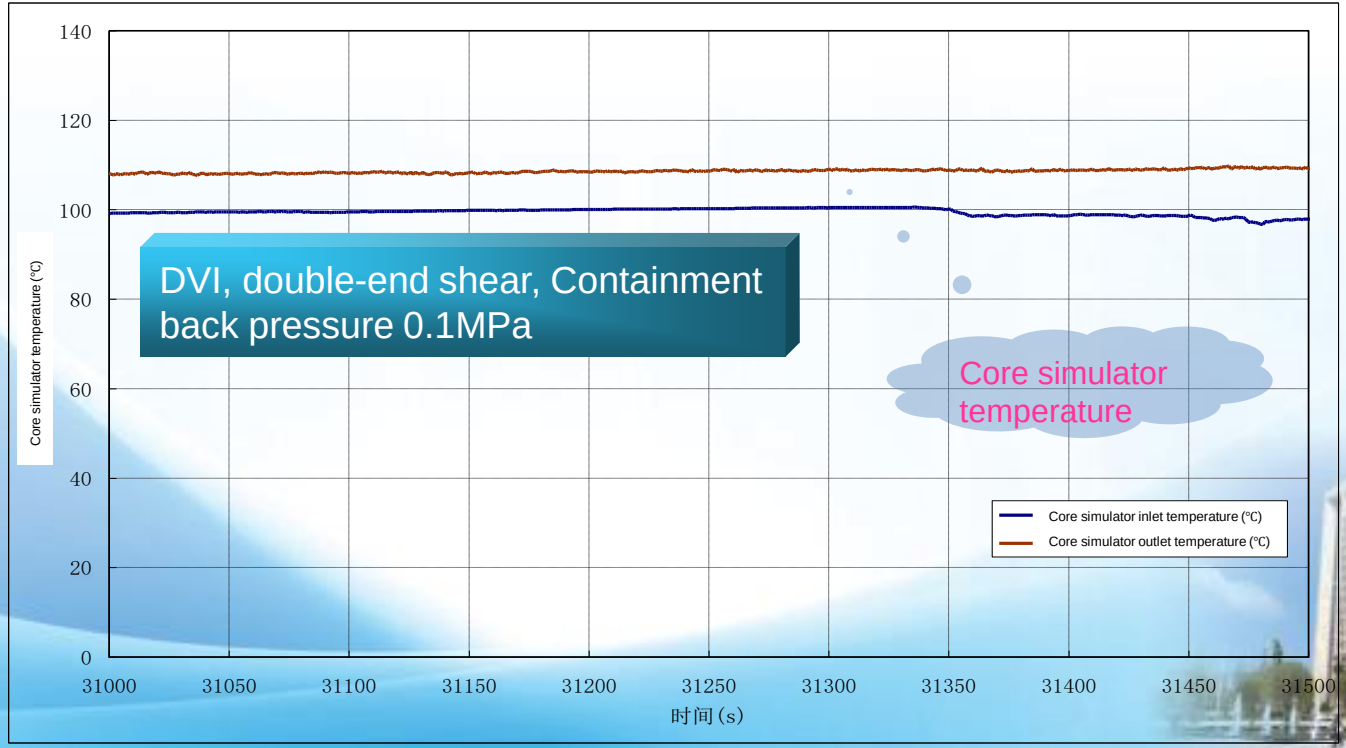


The core is submerged all the time and the maximum temperature at the core outlet is the saturation temperature under the corresponding pressure

Relevant tests (NPIC)

Experiment results

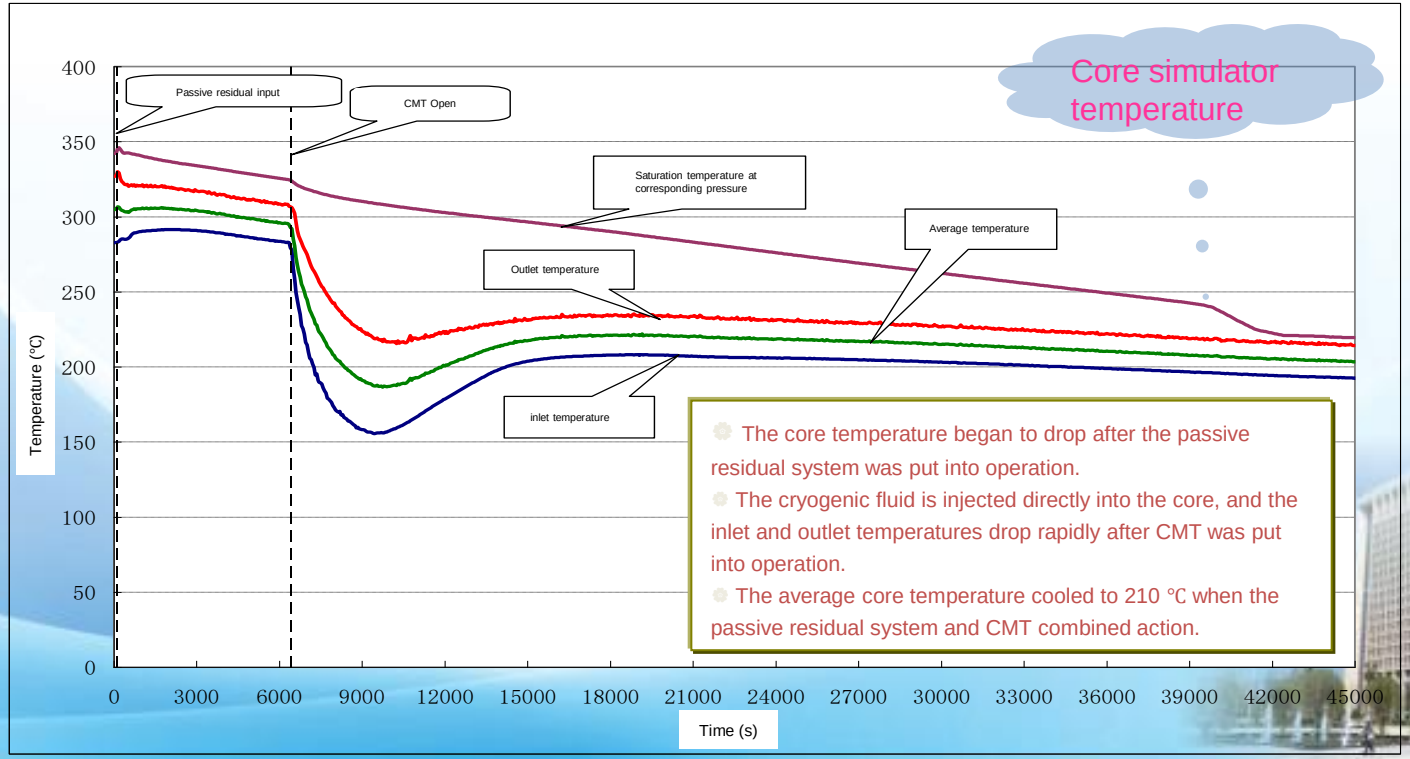
- Experiment of long-term recirculation after water loss



Relevant tests (NPIC)

Experiment results

- Experiment of full-field power failure accident



- The core temperature began to drop after the passive residual system was put into operation.
- The cryogenic fluid is injected directly into the core, and the inlet and outlet temperatures drop rapidly after CMT was put into operation.
- The average core temperature cooled to 210 ℃ when the passive residual system and CMT combined action.

Relevant tests (NPIC)

◆ Thermal hydraulic test facility of supercritical water

❑ Steady-state thermo-hydraulic performance test

The steady-state thermo-hydraulic characteristics of DC steam generator and the influence of single experimental parameter deviation on thermo-hydraulic characteristics are studied.

❑ Dynamic thermal hydraulic characteristic test (Maneuverability)

The thermo-hydraulic characteristics of DC steam generator under different rising and falling power rates are studied.

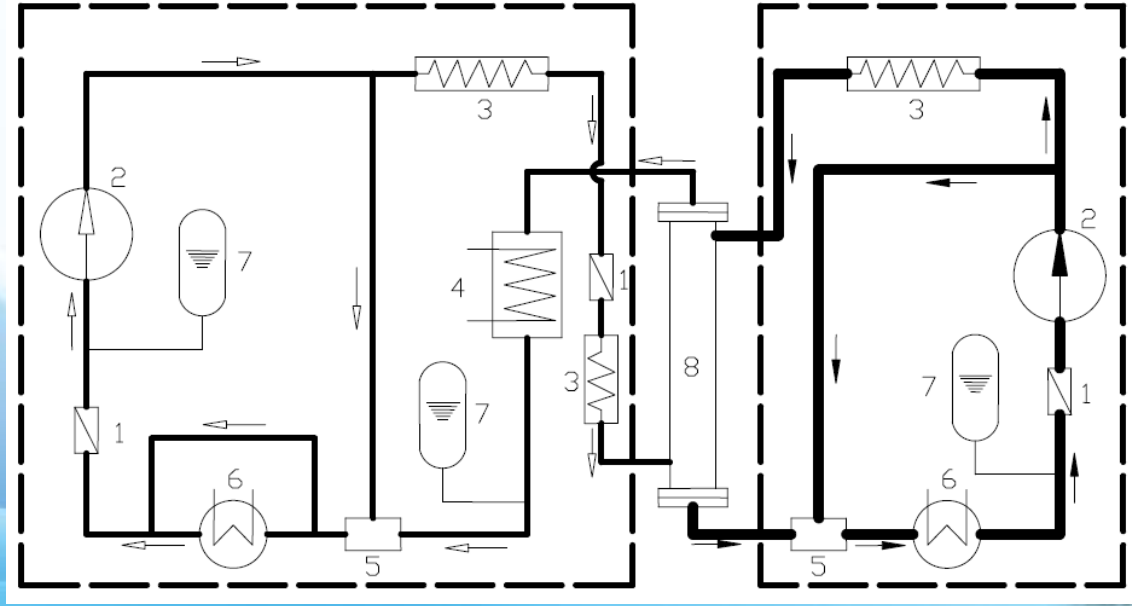
❑ Flow instability test

The critical power of non-periodic flow instability and intertube pulsation in DC steam generator is obtained, and the influence of single experimental parameter deviation on flow instability is studied.

Relevant tests (NPIC)

Installation condition

- Primary loop：design pressure 32MPa, design temperature 450 ℃
- Secondary loop： design pressure 17.5MPa， design temperature 350 ℃



Relevant tests (NPIC)

◆ Large Scale Thermal Hydraulics Test Facility

❑ ACP100

ACP100 carried out three experiments:

(1)Typical cell uniform heating test.

(2)Typical cell non-uniform heating test.

(3)Atypical cell non-uniform heating test.

The experimental parameters are as follows:

- **Pressure: 1.88 ~ 17.5 MPa**
- **Mass flow rate: 272 ~ 1349 kg/(m²s)**

Relevant tests (NPIC)

- **ACP100P** ACP100P carried out five experiments:

  (1)Critical heat flux test with uniform heating of typical cell.

  (2)Critical heat flux test with non-uniform heating of typical cell.

  (3)Critical heat flux test with atypical cell.

  (4)Critical heat flux test occurs before the first structure lattice.

  (5)Critical heat flux lattice spacing sensitivity experiment.

The experimental parameters are as follows:

- **Pressure: 2.0 ~ 17.2 MPa**
- **Mass flow rate: 300 ~ 1600 kg/(m^{2}s)**

Relevant tests (NPIC)

◆ Control Rod Driving Line Test Facility

❑ ACP100 control rod driving line thermal state test

◆Research contents

1. Simulate the fuel assembly high temperature, high pressure hot state scouring test. Test the reliability of its structure and dynamic water corrosion, abrasion and other conditions.

2. Drive mechanism outside the reactor life test: Test its operating life, drop rod can be reliability. Identify the structure in the life period of abrasion and performance index requirements.

3. Function test of falling rod of control rod drive line in various working conditions: Test the time of falling rod of control rod in the case of wrong alignment of drive line.

Relevant tests (NPIC)

Installation condition

Test facility of CRDL thermal state test

ACP100 drive line test piece

Relevant tests (NPIC)

Test completion

◆Research contents

1. The thermal scour time of fuel assembly was 1503.4 hours before seismic test, which tested the service life of fuel assembly under long-term hydraulic scour.
2. The total number of operation steps of the drive mechanism before the seismic test was 6065138, and the operation steps after the seismic test was 1556560.
3. Complete a total of 617 rod drops in the full stroke (including flow sensitivity test). It verified that the rod drop performance of the control rod drive line under the reactor environmental conditions met the design requirements.

Relevant tests (NPIC)

◆ Multi-point excitation test device

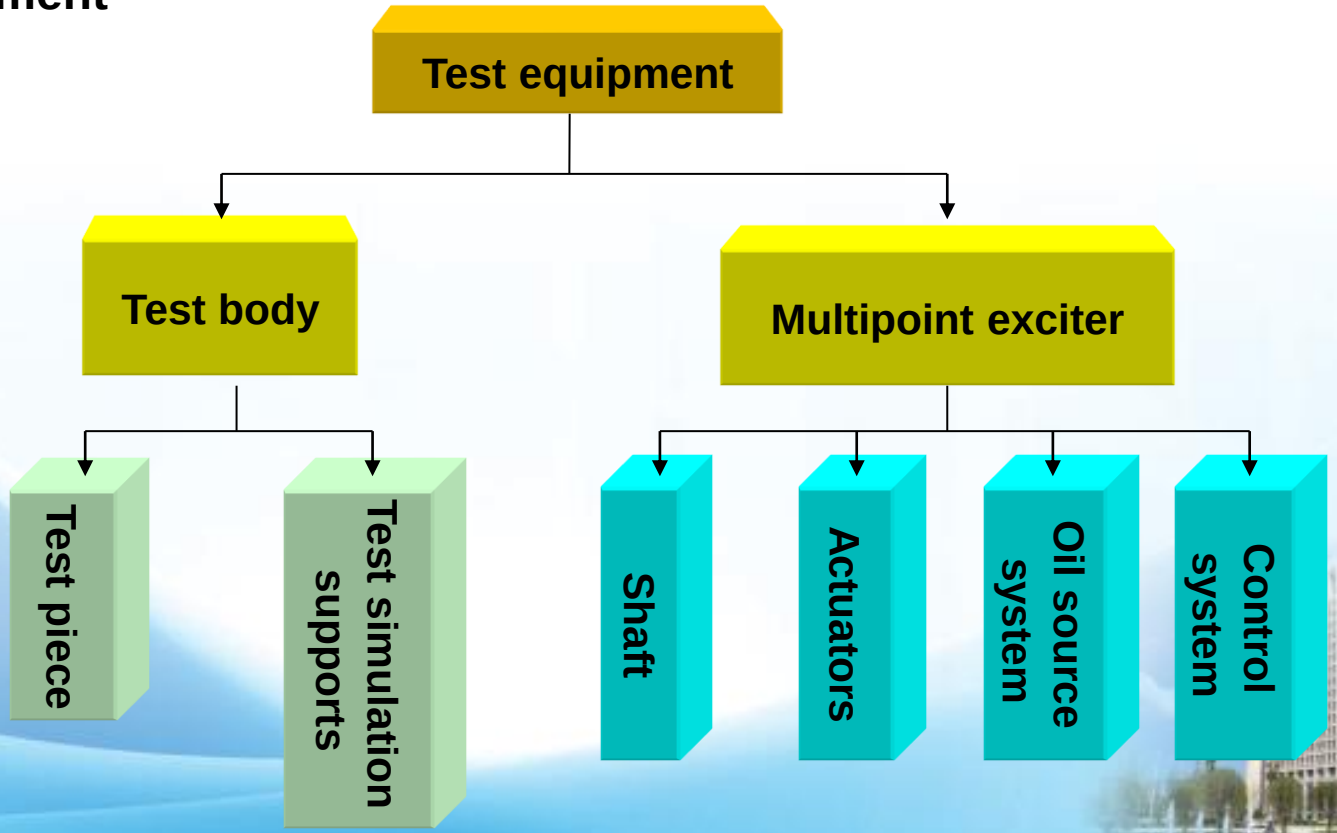
❑ **ACP100 control rod drive line seismic test**

Main contents

- Structural inspection
- Functional tests
- Dynamic characteristic exploration test
- OBE seismic test
- SSE seismic test

Relevant tests (NPIC)

Test equipment



Relevant tests (NPIC)

Main conclusions

1. The design and installation of the seismic test body meet the requirements of the seismic test of the drive line, and the test device simulates the installation od the control rod drive line of the ACP100 reactor in the real reactor.
2. The seismic response displacement of each excitation point in the seismic test can envelope the seismic input displacement.
3. Functional tests before and after OBE and SSE tests show that the operating performance of the drive mechanism is normal. In the course of five OBE seismic tests, the drive mechanism can realize the normal lifting and inserting of control rods, the top position holding, the top position dropping rod and the middle position dropping rod functions.
4. The ACP100 reactor control rod drive mechanism is structurally intact after the test. No parts were found loose and falling off, weld cracking and other phenomena.

Thanks for Your Listening

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