Thermal Hydraulic Analysis of 49-2 Swimming Pool Reactor with a Passive Siphon Breaker

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Introduction of Nuclear facilities of CIAE

List of Nuclear facilities in CIAE

序号 No.	核设施名称 Name of Nuclear Facility	堆 型 Reactor Type	设计功率 Design Power	安全分类 Safety Class
1	中国实验快堆(CEFR)	钠冷快堆 SFR	65MW	III类 Class III
2	中国先进研究堆（CARR）	轻水堆 LWR	60MW	III类 Class III
3	重水研究堆(HWRR)	重水堆 HWR	10MW	II类 Class II
4	49-2 游泳池式反应堆(Pool Reactor)	轻水堆 LWR	3.5MW	II类 Class II
5	原型微型反应堆(Prototype Miniature Reactor)	轻水堆 LWR	27kW	I类 Class I
6	微堆零功率装置(Zero Power Facility of Miniature Reactor)	临界装置 Zero Power Criticality Facility	—	I类 Class I
7	氢化锆固态临界装置(Solid Criticality Facility of Zirconium Hydride)	临界装置Zero Power Criticality Facility	—	I类 Class I
8	DF-VI 快中子临界装置 (DF-VI Fast Neutron Criticality Facility)	临界装置Zero Power Criticality Facility	—	I类 Class I
9	ADS启明星次临界实验装置 (ADS Criticality Test Facility)	次临界装置 Sub-criticality Facility	—	I类 Class I

China Experimental Fast Reactor

CEFR has a thermal power of 65MW and electrical power of 20MW. Its first loading is UO_2, and it is of a pool-type design with a 3 loops (Sodium-Sodium-Water) heat transfer system. The whole project takes an area of 44,000 m^2, and has 16 sub-projects and 219 systems.

China Advance Research Reactor

The nuclear power of CARR is 60MW. The fuel has a plate structure and uses smeared U3Si2-Al with 19.75% enrichment; there are 21 SAs in the core; it is a pool-tank type, light pressure, water cooled, heavy water moderated, anti-neutron sink research reactor.

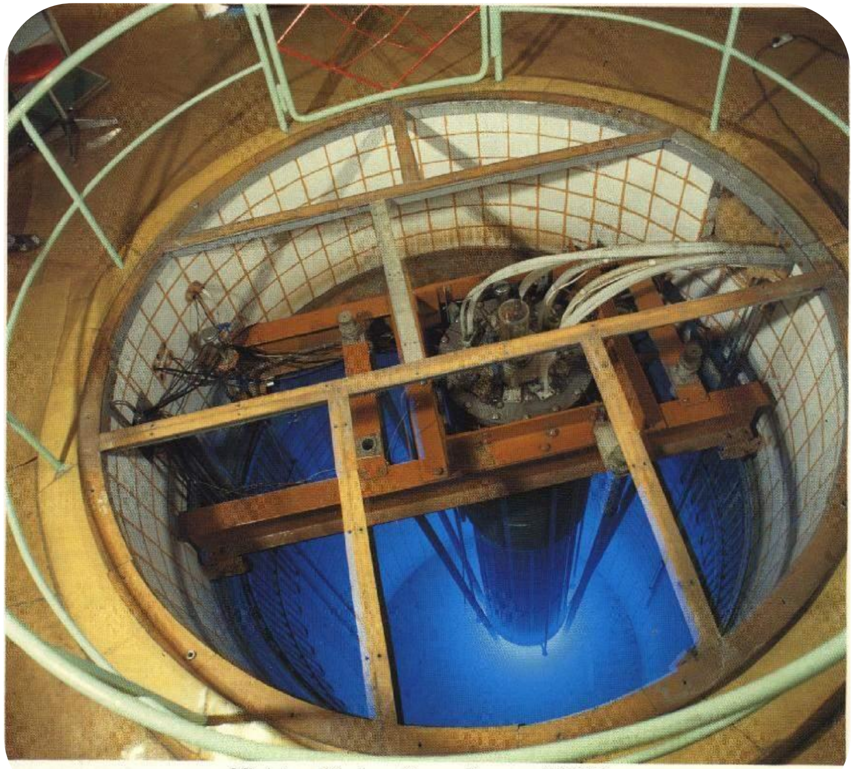
Heavy Water Research Reactor

The HWRR reactor is the first reactor of China. It was operated from 1958 to 2007, and made a great contribution to the nuclear industry development of China. It is now in the preparation stage of decommissioning.

49-2 Pool Type Reactor

It is the first reactor designed and constructed independently by China. It reached first criticality on 20 Dec 1964, and went into power operation in March 1965. it has been operated safely for 53 years. Its main work is on material irradiation, in-core measurement technology research.

Prototype Miniature Reactor



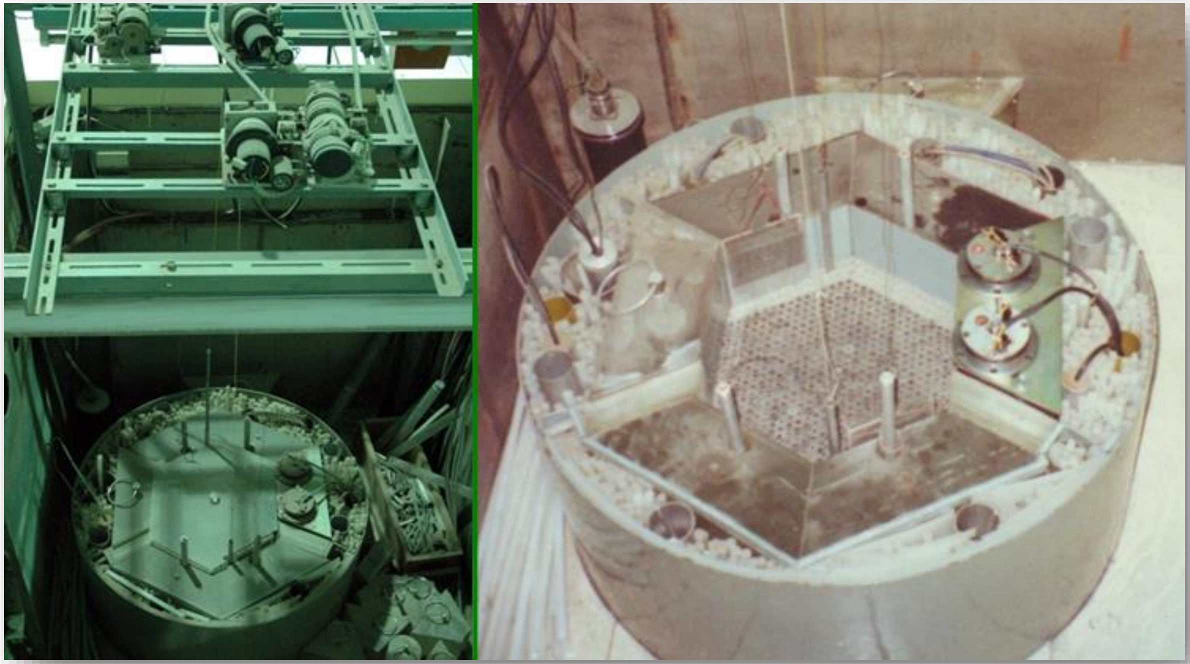
Miniature Neutron Source Reactor (MNSR)

The Prototype Miniature Reactor was established in March 1984, and later 8 commercial miniature reactors were built for several Chinese organizations and countries like Pakistan, Iran, Ghana, Syria, Nigeria, etc. The main usages of miniature reactors are neutron activation analysis, production of short-life nuclides, education and training, and test of instruments.

Critical Facility of DF-VI

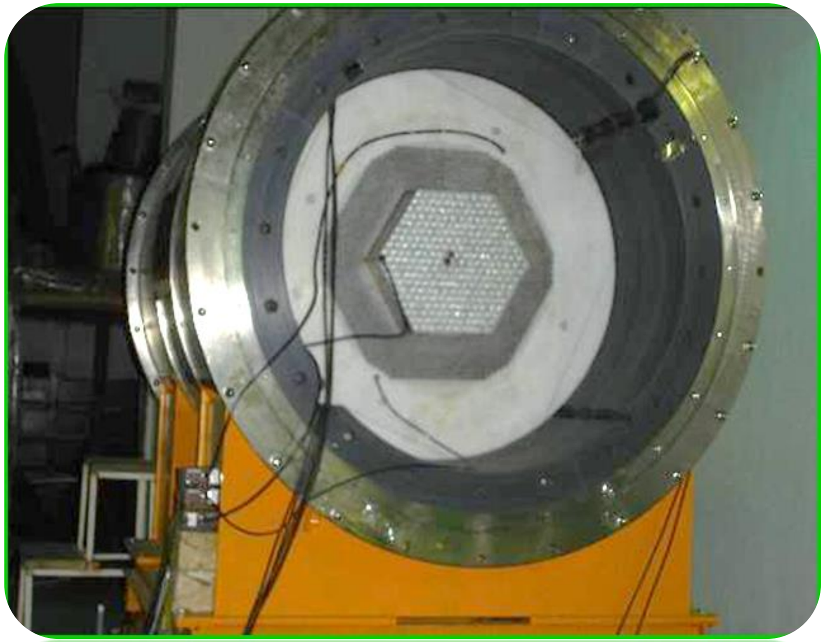
DF-VI is a zero power fast neutron critical facility, and it is mainly used for the research of fast neutron physics and technology. It went to first criticality on 29 June 1970.

Critical Facility with Zirconium Hydride



The Solid Critical Facility with zirconium hydride is a thermal-neutron zero-power test facility with solid hydrogen as moderator.

ADS Subcritical Facility



The ADS subcritical facility consists of a core, neutron measurement system, and instrumentation.

Overview of Safety Reassessment and Improvement of Research Reactors

Safety Assessment after Fukushima Nuclear Accident

As required by NNSA, safety of all nuclear facilities were re- assessed, the following reports were submitted to NNSA：

（1）SMAG for China Experimental Fast Reactor；
（2）Safety Self-examination Report of HWRR；
（3）Safety Self-examination Report of 49-2 Reactor;
（4）Safety Self-examination Report mini Reactor;
（5）Evaluation of Safety Condition of Critical Facilities.

Safety Assessment after Fukushima Nuclear Accident

- Beyond design base accidents were screened and evaluated for different research reactors.

- Investigation and evaluation of tornadoes at the site of CIAE

- The scenario of emergency response caused by accidents from multiple reactors at one site and at same time were studied and evaluated.

Safety Improvements after Fukushima Nuclear Accident

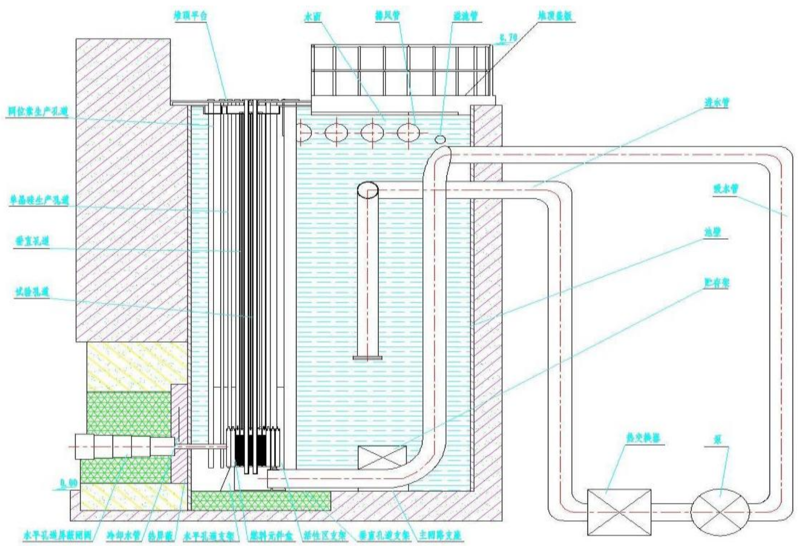
Safety Improvement Measures Based on Experiences and Lessons from Fukushima Nuclear Accident (Overlay of multiple accidents and extreme natural disaster):

1、49-2 reactor

Improving the ability for response to the LOCA and flood, and surveying the aging of the main equipment.

Safety Improvements after Fukushima Nuclear Accident

- In 2012,a siphon breaker was applied to 49-2 reactor, which can break the siphon passively when water pipeline breach and ensure that the core keeps covered by water.



Safety Improvements after Fukushima Nuclear Accident

- The gap between the inlet valve of horizontal tube and the cylindrical body was blockage in order to prevent LOCA due to fracture of horizontal tube under the earthquake of more than M8.0.

- A water barrage was set to prevent flood

- A mobile diesel power supplier can provide power under site blackout

Safety Improvement after Fukushima Nuclear Accident

2. CEFR

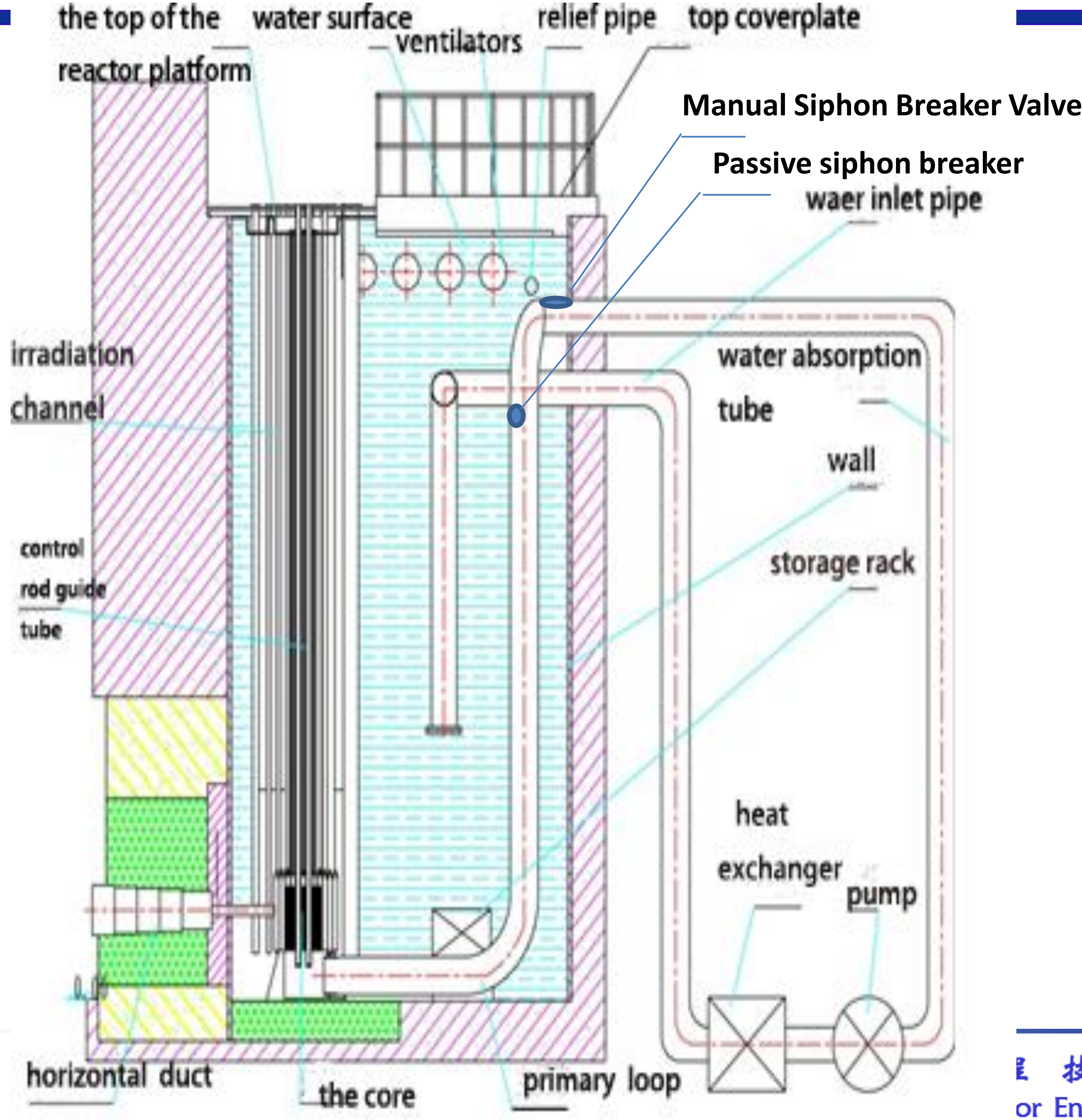
To improve the margin of two lines safety power supply bus bar for the CEFR , an additional emergency diesel power generator (800kW) has been added, while keeping the original configuration of 2 safety diesel generators (728kW).

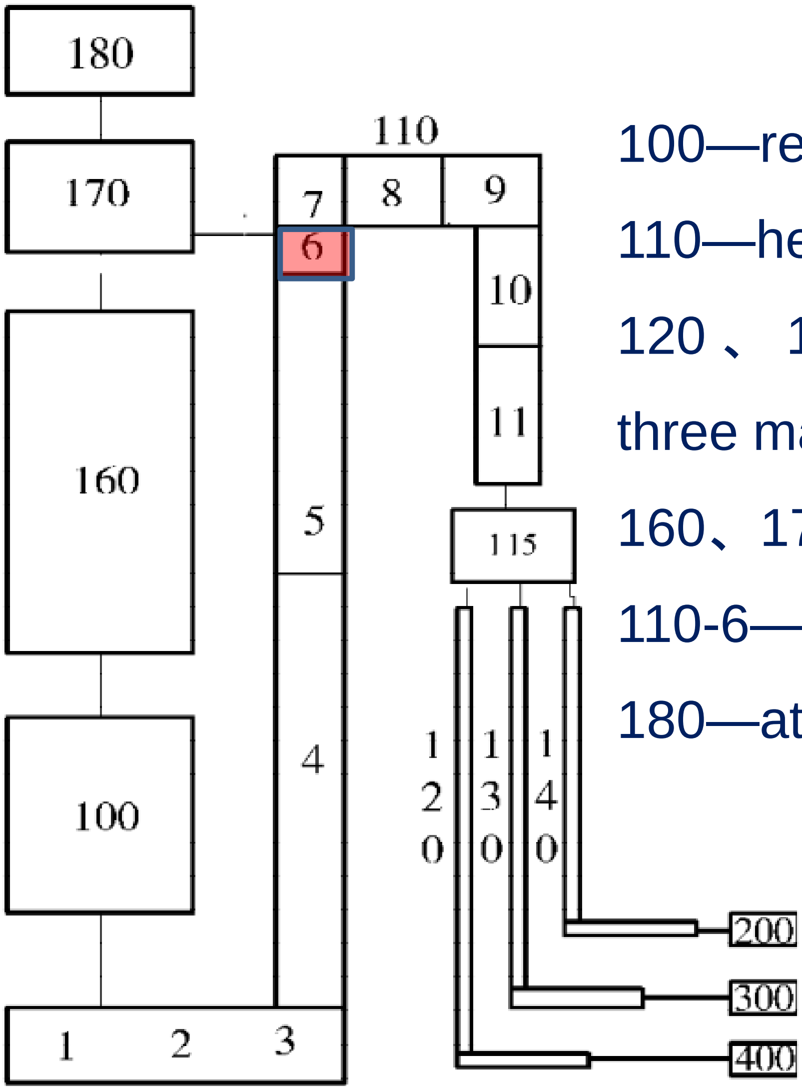
3. Mini reactor and Critical Facilities

Additional UPS and reliable power supply

Thermal hydraulic analysis of 49-2 swimming pool reactor with a passive siphon breaker

Illustration of primary system of 49-2 SPR





100—reactor core

110—heat pipe section of primary coolant loop

120、130、140—branch pipes connecting to three main pumps

160、170—swimming pool over reactor core

110-6—siphon breaker

180—atmosphere over swimming pool

Nodalization of 49-2 SPR using Relap5 code

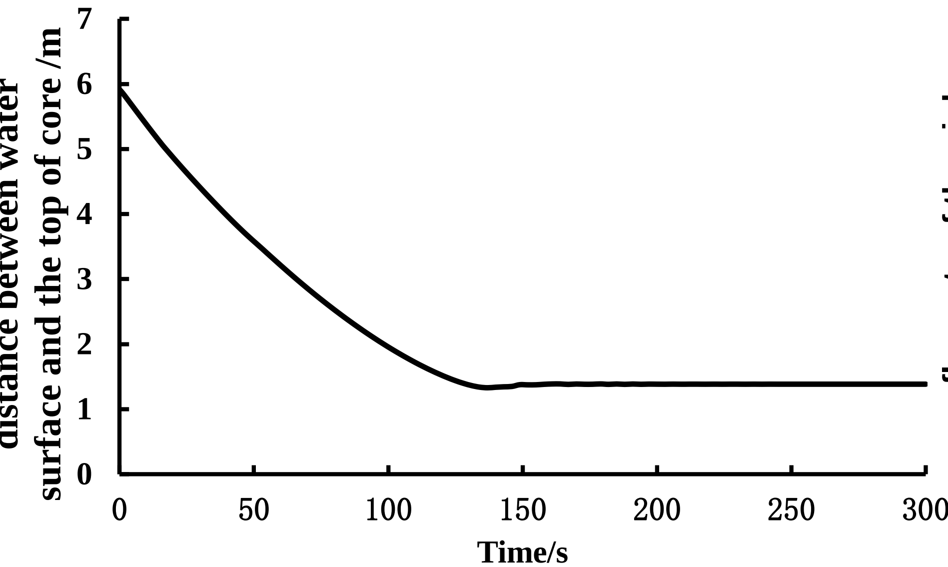
Results Under Steady-State Operating Condition

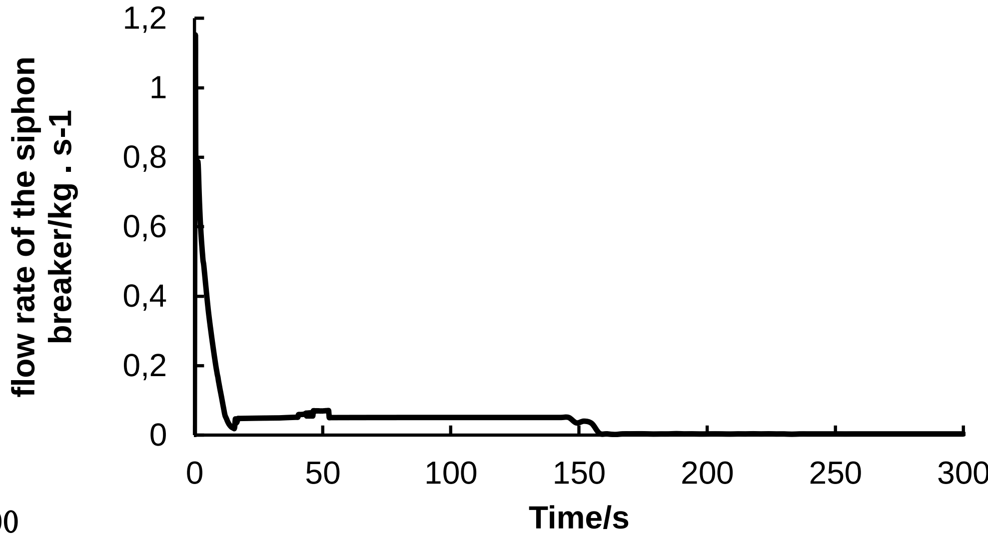
- Under the normal operating condition, the pressure difference between core inlet and outlet is about 8950 Pa, and the flow rate of the core flow is 277.76 kg/s.
- When the siphon breaker's diameter is 1.6 cm, the pressure at the siphon breaker is about 87485 Pa, the flow through the siphon breaker is about 1.90 kg / s, the flow rate of the coolant flowing through the core is 277.45 kg / s, which indicates its impact on the core flow is only 0.11%.
- It can be seen from the calculation that a siphon breaker with diameter of 1.6 cm has a very small effect on the core coolant, and has no influence on the normal operation of the reactor.

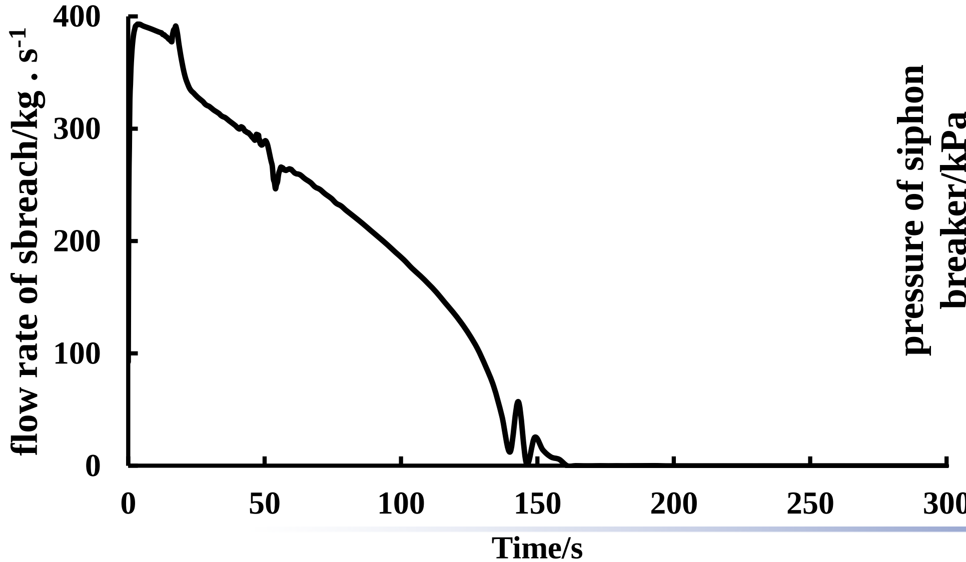
Basic assumptions for LBLOCA condition

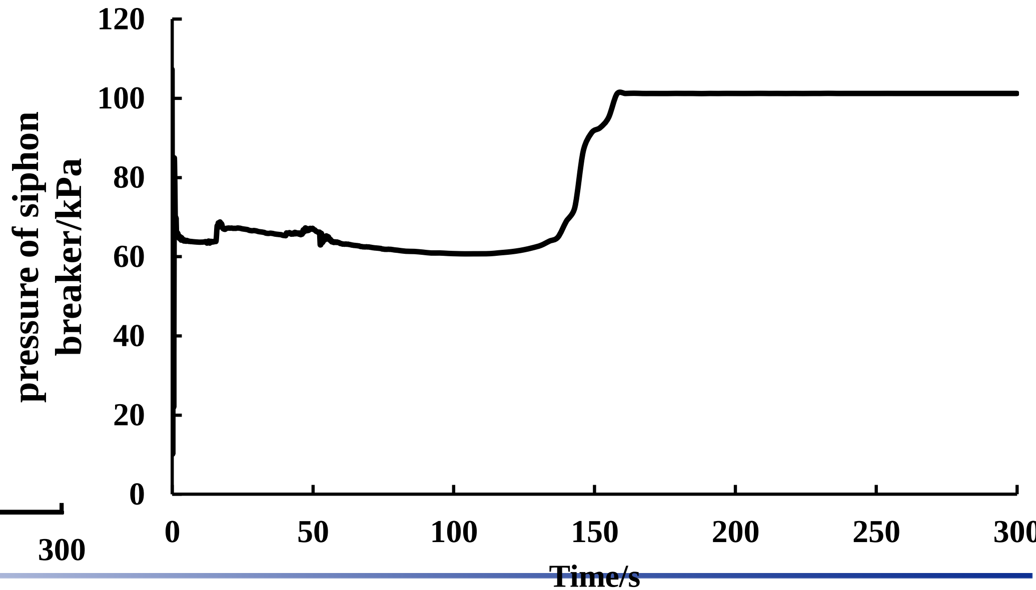
- LBLOCA occurs in the front part of the primary loop pump during the reactor shutdown period, and the break diameter is 265 mm, the its elevation is 0.07 m.
- The elevation of the water in the pool is 7.15 m (distance between the water surface and the upper surface of the core is 5.91 m).
- All engineered safety features cannot be put into operation.
- There is no flow resistance in the pipe when siphon occurs.

Results of LBLOCA





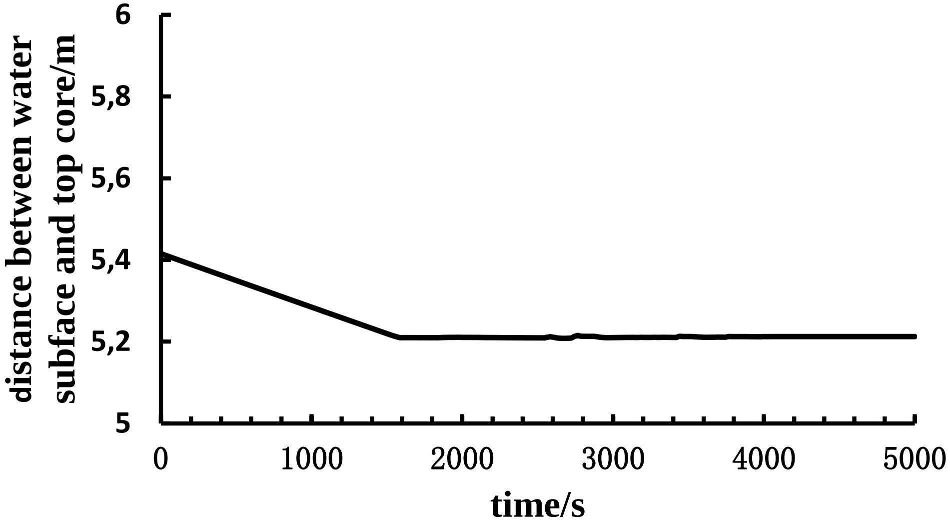


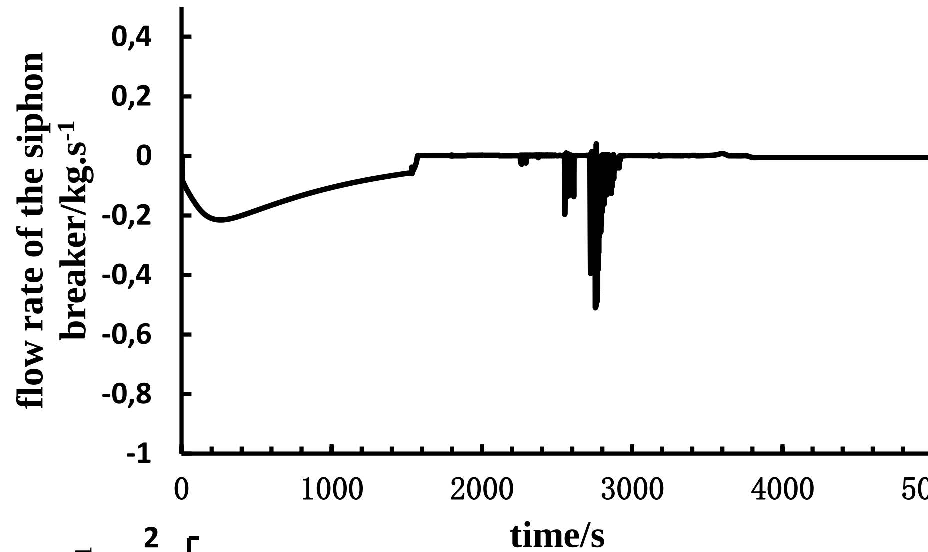


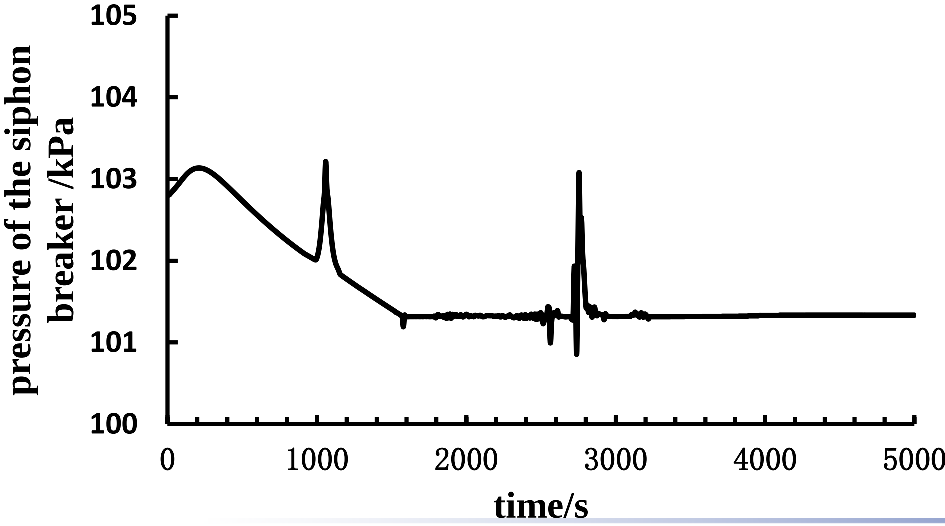
Basic assumptions for SBLOCA condition

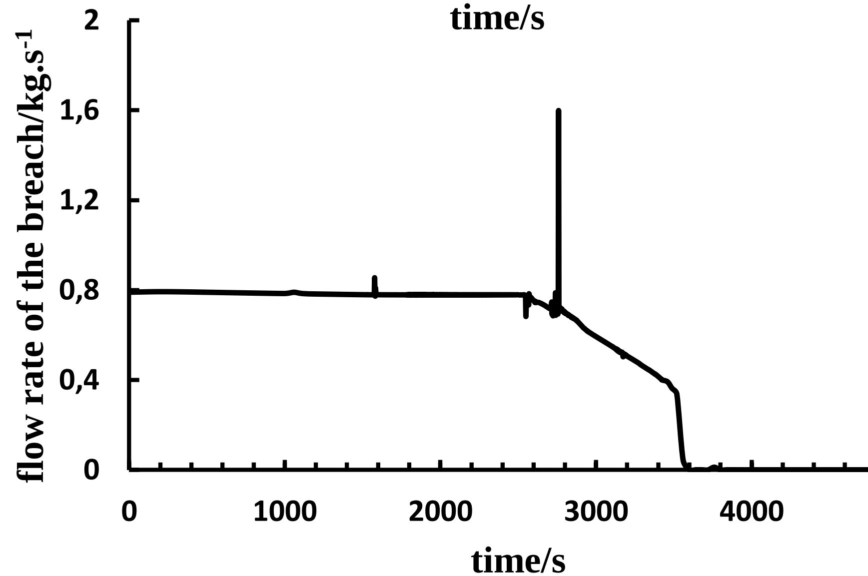
- SBLOCA occurs in the front part of the primary loop pump during the reactor shutdown period, and the break diameter is 1.6cm, its elevation is 0.07 m.
- To present the calculation results clearly, it is assumed that the elevation of the water in the pool is 6.65 m (distance between the water surface and the upper surface of the core is 5.41 m).
- All engineered safety features cannot be put into operation.
- There is no flow resistance in the pipe when siphon occurs.

Results of SBLOCA









Conclusion

- A 1.6 cm passive siphon breaker basically has no negative effects on the steady-state operation of the reactor;
- It can stop siphon and prevent core uncovering when LBLOCA accident occurs as the reactor and pump shutdown;
- It has sufficient margin to stop siphon and ensure the core safety when SBLOCA accident occurs as the reactor and pump shutdown.

THANKS

谢 谢 聆 听