Chinese SCWR R&D in NPIC

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Nuclear Power Institute of China (NPIC) is one important R&D unit of CNNC (China National Nuclear Corporation). There are so many outstanding achivements in the histroy of the NPIC.

1. 1st PWR in China in 1970;
2. 1st High Flux Engineering Test Reactor of China;
3. 1st Pulsed Reactor of China with U-ZrHAl fuel;
4. 600MW NPP of Qinshan Phase-II.

NPIC covers many fields of nuclear engineering:

1. R&D;
2. Design;
3. Reactor operation;
4. Productions and services.

R&D supported by:

There are 98 research labs to run more than 50 majors and subjects. They belong to three national key labs, the national key laboratory for nuclear reactor system design technology, the national key laboratory of bubble physics and natural circulation, and the national key laboratory for nuclear fuel and materials.

There are 15 large scale test facilities:

1. Nuclear Power Component Comprehensive Test Facility
2. Reactor Hydraulic Modeling Test Loop
3. Control Rod Drive Mechanism Hydraulic Cold Test Facility
4. Control Rod Drive Mechanism Hydraulic Hot Test Facility
5. Test Facility for APWR Secondary Passive Emergency Core Residual Heat Removal System
6. Control Rod Drive Mechanism Anti-Seismic Test Well
7. Reaction Wall and Load Carrying Base for Mechanic Test
8. Fatigue and Blast out Test Facility
9. Multifunctional Material Test Machine

10. Freon Thermal-hydraulic Test Facility

11. Large-scale Thermal-hydraulic Test Facility

12. Water-chemistry Test Facility

13. 6m×6m Seismic Rig

14. Main Pump Test Facility

15. Failure Diagnosis Test Facility

And there are 3 research reactors running by NPIC.

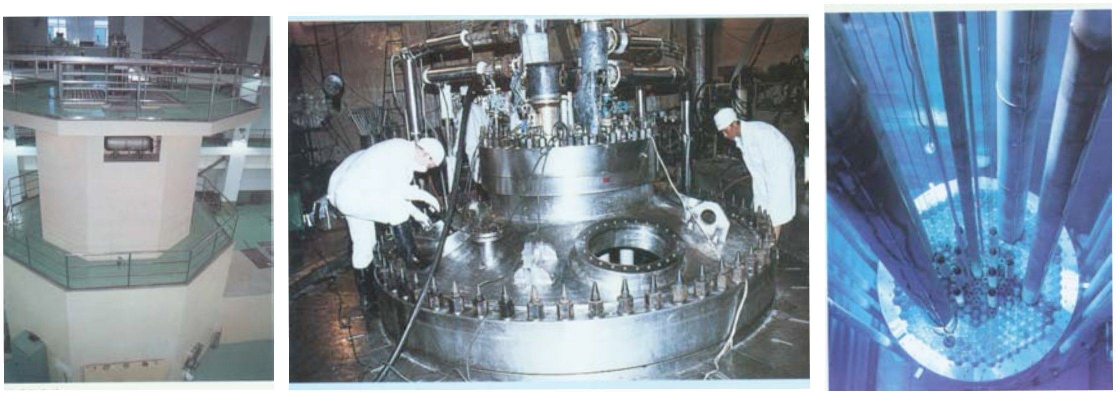


Figure 1 the three reactors

Figure 2 Large-scale Thermal-hydraulic Test Facility


Figure 3 CRD Mechanism Hydraulic Hot Test Facility Figure 4 Water-chemistry Test Facility

Figure 5 CRD Mechanism Anti-Seismic Test Well

Figure 6 6m×6m Seismic Rig

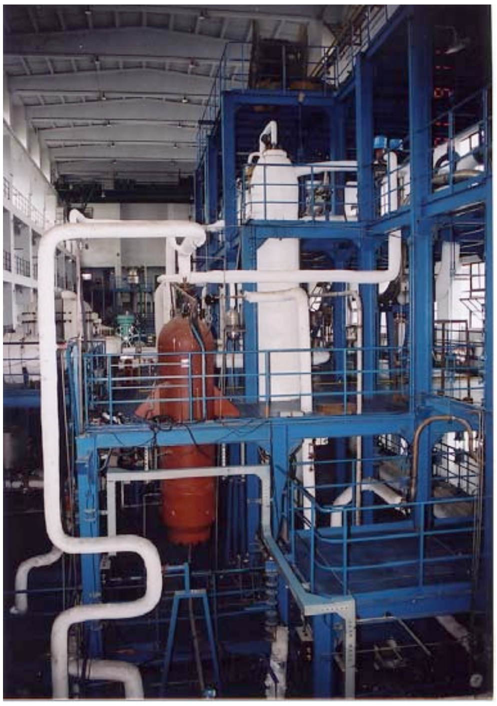


Figure 6 Nuclear Power Component Comprehensive Test Facility

With the fast growth of the China’s economy, NPIC is building a new research center now. The phase I investment of the new research center of NPIC is 1.4b RMB, and its area is 600,000 m^2 in Chengdu.

Figure 7 New research base

SCWR is NPIC's choice for two points:

1) SCWR is promising

- High efficiency
- Simplified system
- Low cost
- More support can be obtained from BWR and PWR
- Steam turbine is tested in SC fossil power plants

2) NPIC has very strong research background on LWR

PT and PV type SCWR for Chinese SCWR

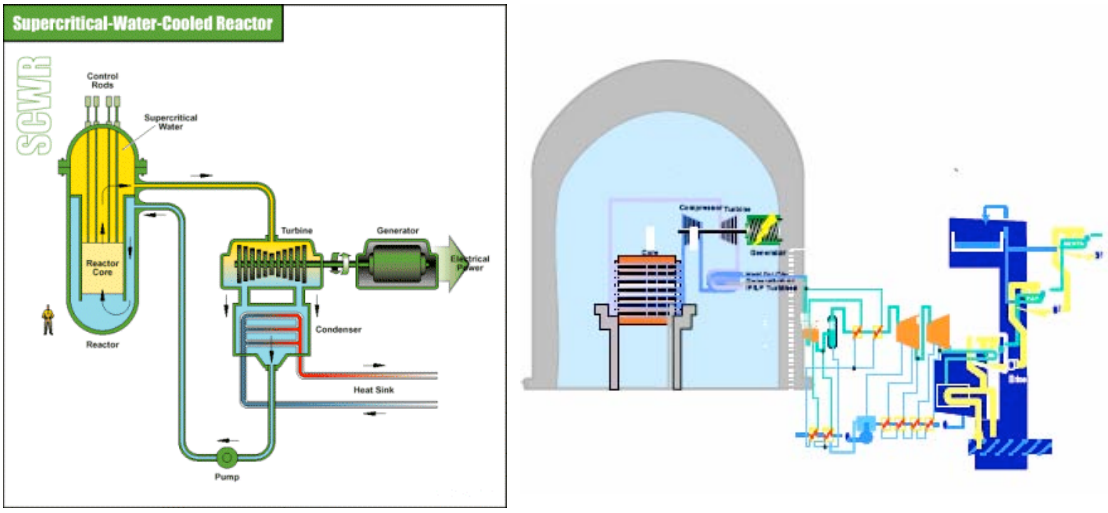


Figure 8 PT and PV type

The parameters for Chinese SCWR selected is followed:

Table 1 Main Parameters

Output electrical power:	1500MWe
Core thermal power:	3400MWt
Plant efficiency:	44%
Core neutron spectrum:	Thermal
Main system type:	Direct cycle
Operation pressure of main system:	25MPa
Core inlet/outlet temperatures:	290℃/560℃
Number /type of Fuel Assemblies:	157/square
Core active length	4.3m

The schedule of Chinese SCWR in our plan:

Table 2 Schedule of the SCWR in China

ITEM	**FROM**	**END**
R&D Program	**Jan. 1, 2009**	**Jun. 29, 2021**
Top-tier design requirements and overall planning	Jan. 1, 2009	Dec. 31, 2009
Program verificaiton	Jan. 1, 2009	Dec. 31, 2009

ITEM	FROM	END
Feasibility verificaiton	Jan. 4, 2010	Jul. 4, 2011
Basic techinics R&D	Jan. 1, 2009	Dec. 31, 2016
Program design and feasibility verification	Jul. 5, 2011	Dec. 8, 2015
Engineering technics R&D	Jan. 3, 2012	Deec. 31, 2019
initial design	Dec. 9, 2015	Dec. 10, 2018
Detailed desing	Jan. 1, 2019	Jun. 29, 2021
R&D facilities and platforms	**Jan. 5, 2010**	**Dec. 1, 2022**
Basic research facilities construction	Jan. 5, 2010	Dec. 5, 2011
Engineering research facilities constrution	Jul. 2, 2012	Dec. 1, 2014
Key technics R&D platform developing	Dec. 5, 2011	Jun. 30, 2015
Operation related platform R&D	Dec. 4, 2018	Dec. 1, 2022
Demonstration program	**Jan. 6, 2020**	**Jan. 6, 2025**
FCD		Jan. 6, 2020
PSAR		Oct. 5, 2023
1st fueling		Oct. 6, 2024
1st critical point		Jan. 6, 2025

The Conceptual design and feasibility study

In 2007, NPIC performed an initial conceptual design for Pressure Vessel type SCWR.

The conceptual design and investigation were performed in the following aspects:

-core nuclear design

-core thermal/hydraulics design

-FA

-safety systems

-safety evaluation etc.

In 2008, NPIC performed design studies for Pressure Tube type SCWR

The emphasis of the study is the passive safety systems.

1) Test facilities

2) SCW Autoclave

The in-core SCW Radiation Test Loop (under construction on MJTR) is shown by the figure 9 as follows:

Figure 9 Radiation Test Loop

The general corrosion behaviors of the alloys were investigated:

—Corrosion-resistant performance

—Oxide morphology and thickness

—Oxide structure and composition

—Corrosion mechanism

The following table 3 will show the experimental conditions for SCW corrosion in NPIC.

Table 3 Experimental Conditons

Alloy Class	Alloy	Temp.(℃)	Water chemistry	Exposure time (hr)
Ferritic-Martenstic	P91, P92, K1(12Cr), K2(9Cr)	500-600	30 ppb dissolved oxygen	0-1000
Austenitic SS	316, 316L, 304NG, 310, 6XN	500-600	30 ppb dissolved oxygen	0-1000
Nickel-base	625, X750, 718, C276, 690	500-600	30 ppb dissolved oxygen	0-1000

Alloy Class	Alloy	Temp.(℃)	Water chemistry	Exposure time (hr)
ODS	9Cr, 12Cr, 19Cr-4Al	500-600	30 ppb dissolved oxygen	0-1000

And the experimental results from material corrosion is shown as follows:

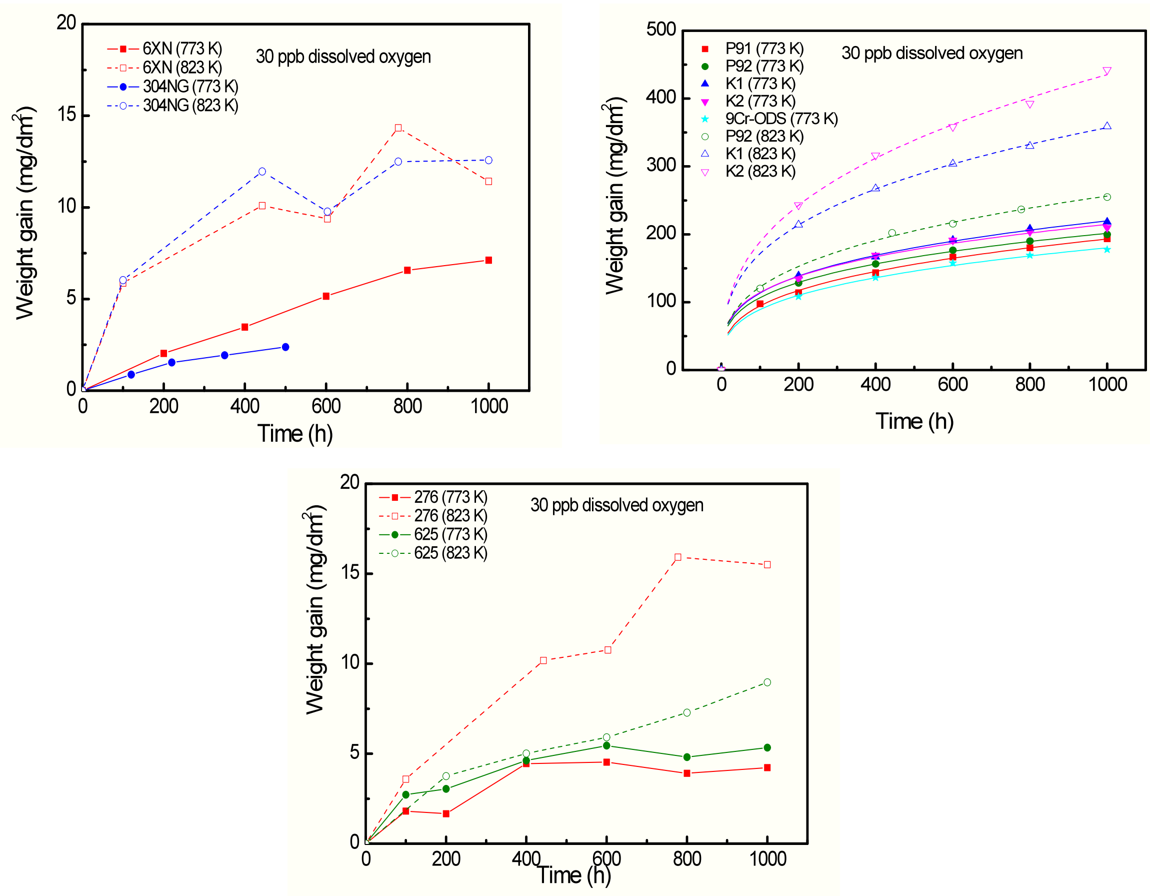


Figure 10 Results of the corrosion experiments

Medium Scale T/H Test Loop

Table 4 Parameters of the test loop

Design pressure	30.0 MPa
Operating pressure	25.0 MPa
Design temperature	550 ℃
Operating temperature	500 ℃
Flow rate	20 m^3/h
Heating power	10.0 MW
Working fluid	Deionized water

The following figure 11 give the design of the thermal-hydraulics test loop.

Figure 11 the test loop

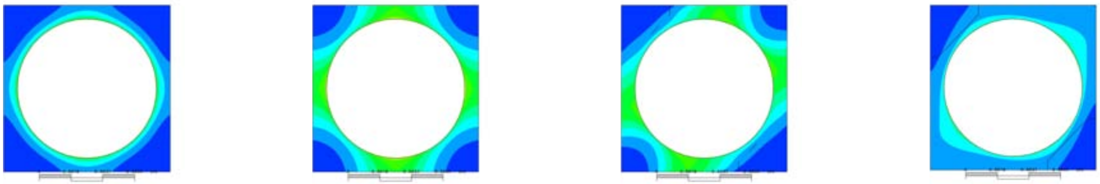
Two experiments are to be performed on Basic T/H Test Loop in 2009. One is the heat transfer experiment with SCW in round tube, and the other is the flow resistance investigation in round tube.

Now CFD is applied to analyze behavior of SCW heat transfer and flow:

- Evaluation on turbulence model for SCW T/H prediction

- Investigate insert effect to flow and heat transfer

The figure 12 shows the temperature contour along the channel with the equal distance.



0.1m 0.4m 0.7m 1.0m

Figure 12 Temperature contour along channel with equal distance

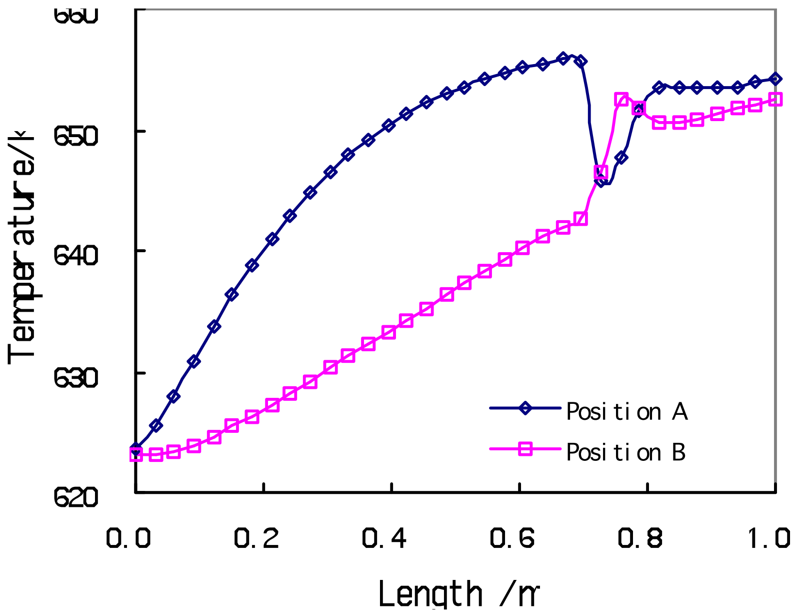


Figure 13 Axial temperature with vane

A kind of codes has been developed for neutron physic calculations named as SCCS（SuperCritical Core Simulator）.

- It’s developed for PV and PT type SCWR;

- Burnup calculation;

- Satisfy the need of FA evaluation;

- Neutron calculation can treat FA with inner duct wall;

- Calculation can cover the future need of core design, FA management, accident analysis and etc.

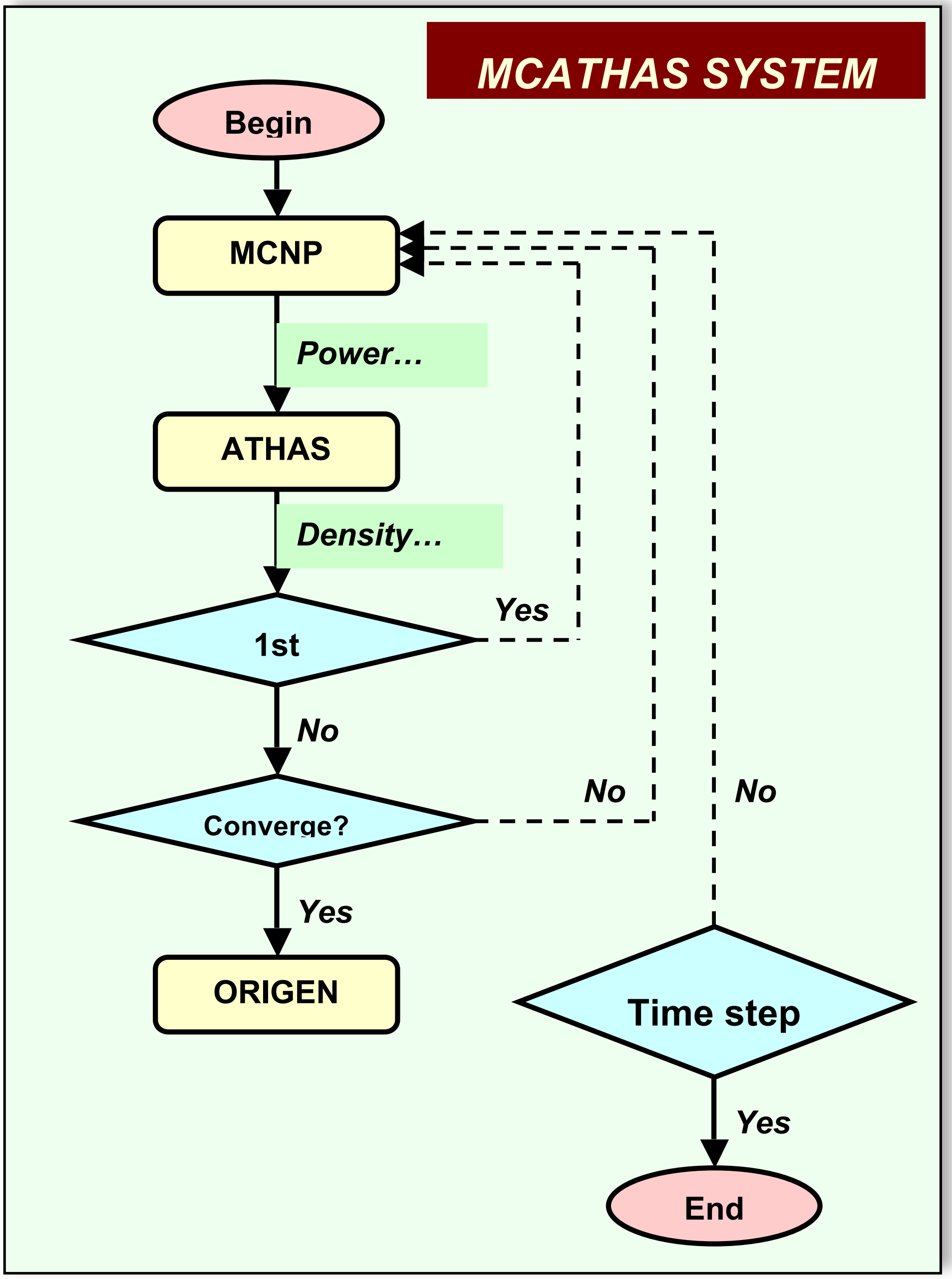


Figure 14 the structure of the codes

MCATHAS system considers the mutual influence between the strong density and temperature variation of material and the axial relative power distribution.

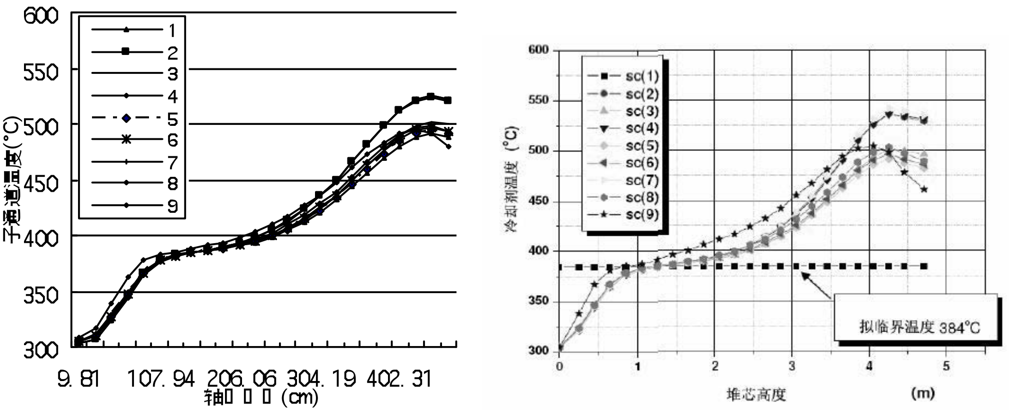


Figure 15 Axial coolant temperature distribution of sub-channel

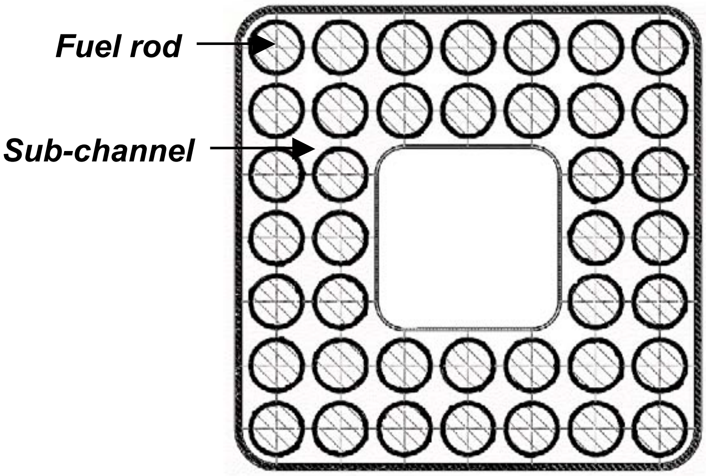


Figure 16 Assembly of SCWR

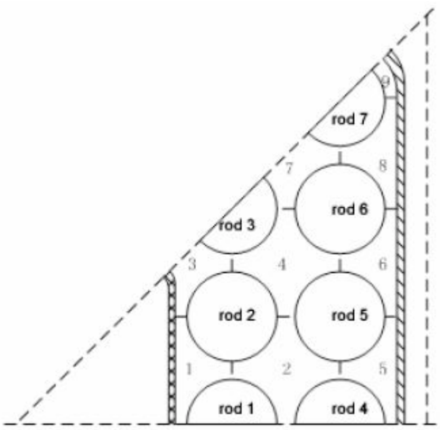
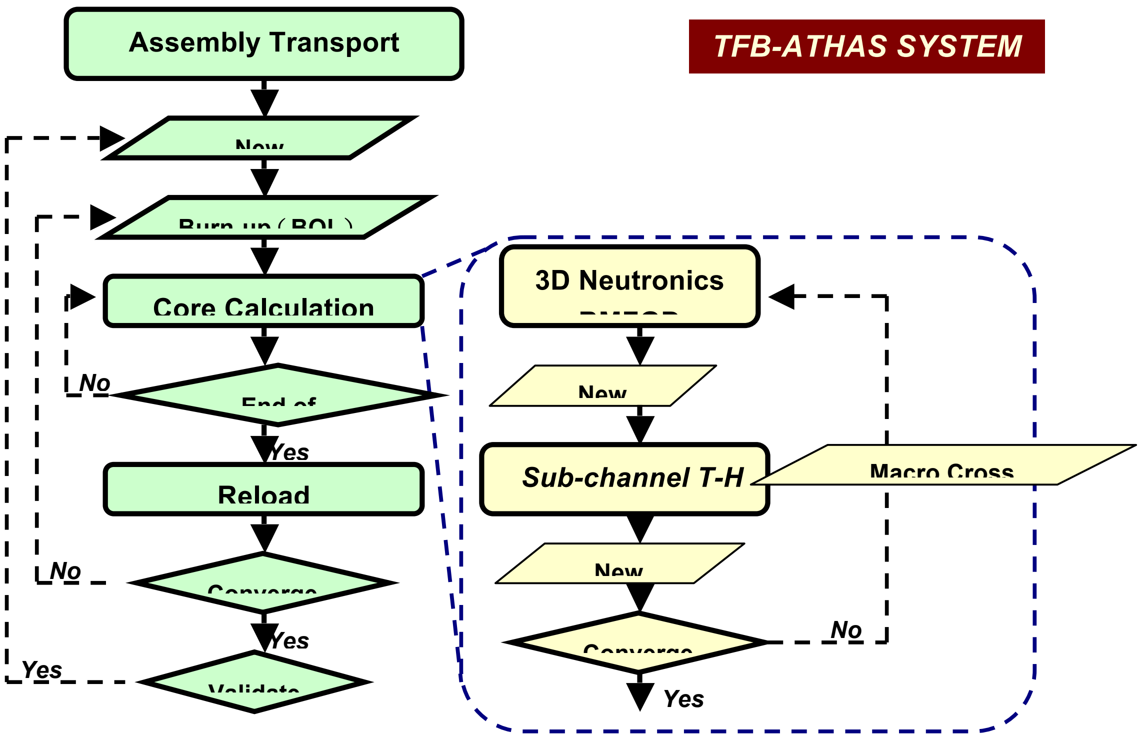


Figure 17 1/8 Assembly of SCWR



TFB-ATHAS SYSTEM is builed by 3 codes, which are TPFAP-E (Assembly neutron transport), BMFGD (3D diffusion finite difference), and ATHAS (Sub-channel thermal-hydraulic).

Its functions is as follows:

- Coupled Calculations of Neutronics and Thermal-hydraulic

- Core Reload

- Coefficient of Reactivity

- Kinetic Parameters

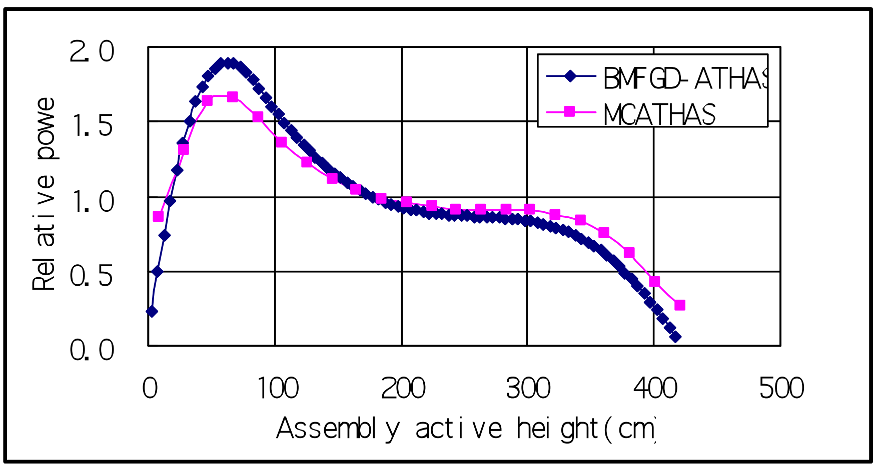


Figure 18 Axial relative power distribution of assembly

The Cooperation on the SCWR research is very important. It will increase the R&D of SCWR and enhance the safety of SCWR.

Now, NPIC needs cooperations on the items as follows:

1) Conceptual design and feasibility study

NPIC has issued a set of top-tier design requirements and overall planning for Chinese SCWR R&D.

2) Top-tier design requirements and overall planning for SCWR R&D

The top-tier design requirements issued include the technical and economical indicators and general technical requirements, such as CDF, output electrical power, design life, plant specific investment etc.

NPIC proposes to exchange ideas in the top-tier design requirements and overall planning by exchanges of documents of both parties discussions in meetings.

3) Corrosion and SCC

- Long-term corrosion behavior (autoclave and loop)
- SCC
- Oxide characterization

4) High temperature strength

- Tensile property
- Thermal creep

5) Radiation damage

- Embrittlement
- Irradiation induced creep
- Swelling

6) Thermal-hydraulics:

- Experimental study on deterioration of heat transfer
- SCW flow instability
- Code developing
- Safety analysis