

Accident Tolerant Fuel Research Activities in CGN

Nuclear Fuel R&D Center
China General Nuclear Power Corporation(CGN)

April 30, 2014



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1. Brief introduction of R&D in CGN
2. ATF related activities in China
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1. Brief introduction of R&D in CGN

□ About China General Nuclear

A large clean energy group under the supervision of the State-owned Assets Supervision and Administration Commission (SASAC) of the State Council of China

- GNPS
- start from a high level
- construction with loans, repayment by electricity sales, operation through joint venture



first large commercial nuclear power station in mainland China

- LNPS Phase II, HNPS, NNPS, YNPS, FNPS, CPR1000
- TNPS (3G technology — EPR)
- developing renewable energies such as wind power, hydropower and solar energy etc.



- realizing “four self-reliance” capabilities

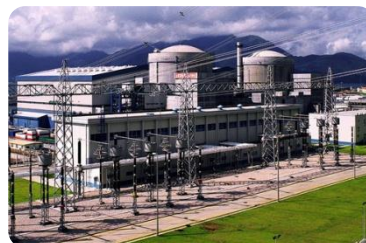
Pioneering period
1979-1994

Development period
1995-2004

Second pioneering
period
2005-2011

Post-Fukushima
period
2012 —

- LNPS Phase I
- self-reliant development of nuclear power per international standards



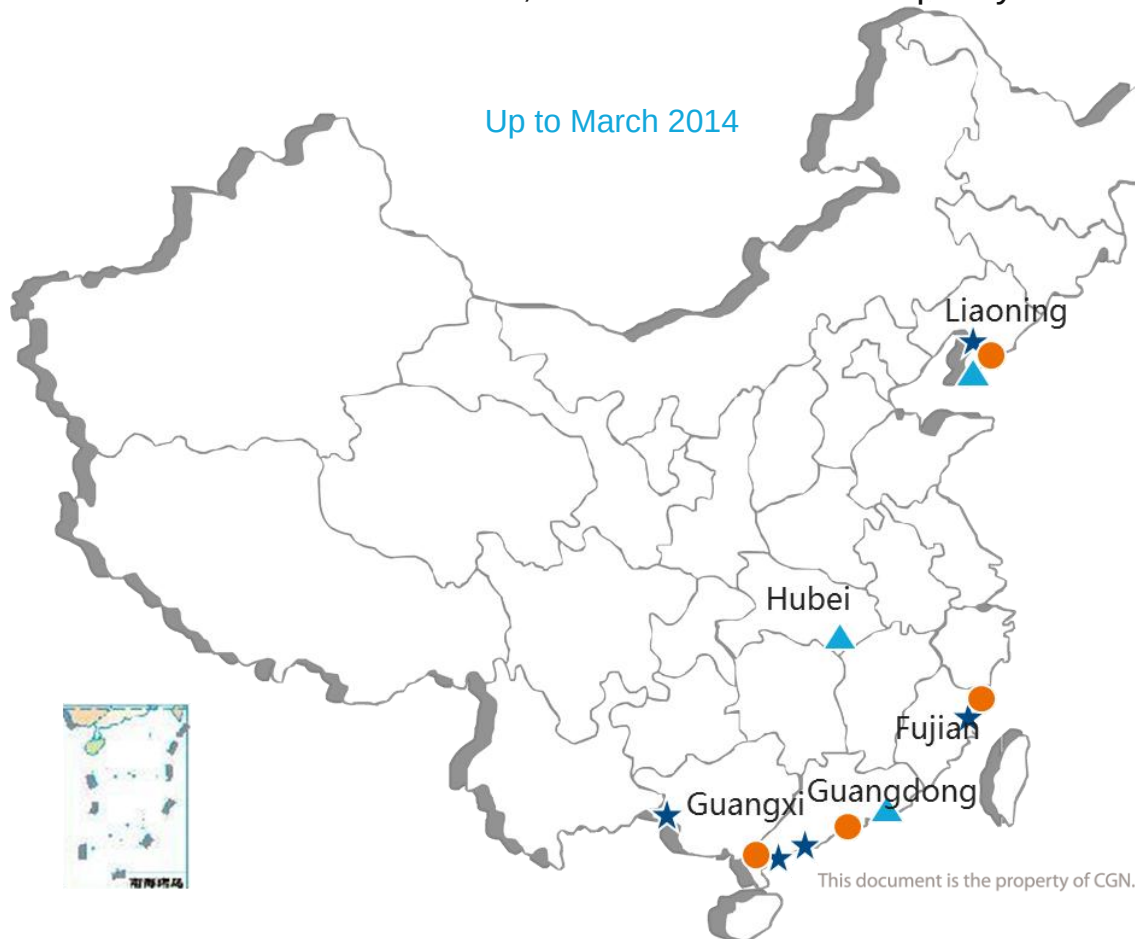
- developing proprietary advanced PWR technology — ACPR1000+
- building world's first-class clean energy corporation

1. Brief introduction of R&D in CGN

□ CGN nuclear power supply

CGN's NPP capacity currently under construction account for ~25% of the global total amount.

- 9 units in operation, with a total installed capacity of 9.41 million kW
- 15 units under construction, with a total installed capacity of 17.72 million kW



● in operation

GNPS

LNPS Phase I

LNPS Phase II

Unit 1 of Ningde NPP Phase I

Unit 1 of Hongyanhe NPP Phase I

Unit 1 of Yangjiang NPP

★ under construction

Units 2/3/4 of Ningde NPP Phase I, Fujian

Unit 2/3/4 of Hongyanhe NPP Phase I, Liaoning

Unit 2-6 of Yangjiang, Guangdong

Taishan Phase I, Guangdong

Fangchenggang Phase I, Guangxi

▲ under review

Lufeng project, Guangdong

Hongyanhe Phase II, Liaoning

Xianning project, Hubei

1. Brief introduction of R&D in CGN

□ Research and development

- CGN is building 15 R&D centers, including 6 national energy R&D (experiment) centers, including National Energy R&D Center of Advanced Nuclear Fuel.

Four strategic projects

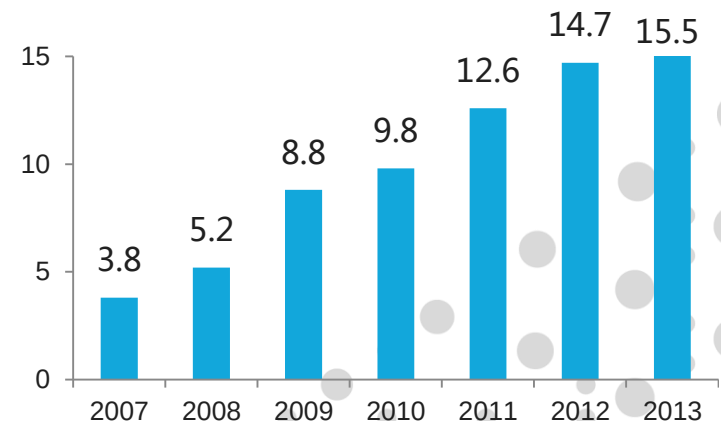
- R&D on ACPR1000+ reactor
- R&D on advanced fuel assembly
- Small reactors
- Advanced nuclear energy system

Twenty top programs

- R&D on CRDM and other key nuclear equipment
- R&D on evaluation and management of plant life
- Nuclear-safety related digital I&C system
- Concentrated solar power technology
- R&D on key simulation technology and simulator

- Investment in technological innovation has increased from RMB 380 million Yuan in 2007 to RMB 1550 million Yuan in 2013.

Expenditure of technological activities:(in 100 million Yuan)



1. Brief introduction of R&D in CGN

□ National Energy R&D Center of Advanced Nuclear Fuel

- Founded in July 2010, the nuclear fuel center has established a technical team with more than 60 staffs, cover different major related to nuclear fuel R&D.

国家能源先进核燃料元件
研发（实验）中心

国家能源局

National Energy Administration

National Energy R&D Center of Advanced Nuclear Fuel

Nuclear Fuel R&D Center of CGN

Academic Committee

Dep of SD

Dep of SM

Dep of PA

Dep of EV

Dep of PT

Dep of I&T

Dep of GT

SD: Structure Design

SM: Structure Material research

PA : Performance Analysis and software development

EV: Experiment Verification PT: Physics & Thermal

I&T: Irradiation and Test

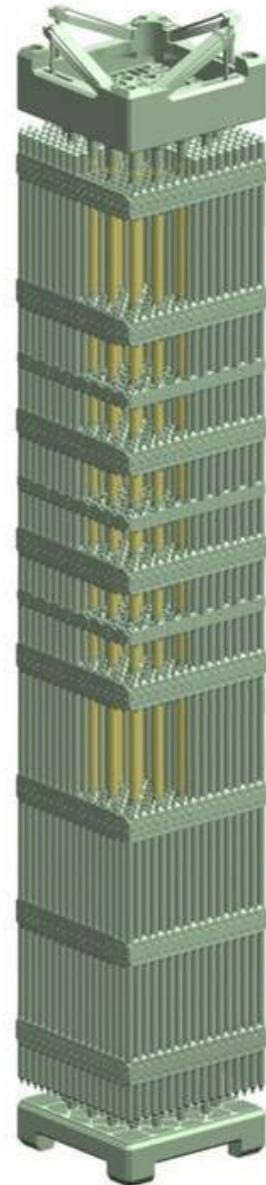
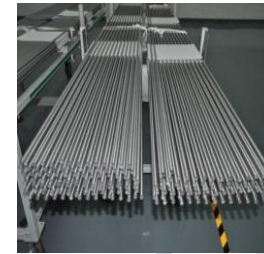
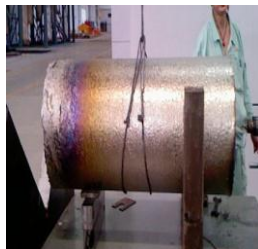
GT: General Technology research

1. Brief introduction of R&D in CGN

□ National Energy R&D Center of Advanced Nuclear Fuel (cont.)

Key research fields

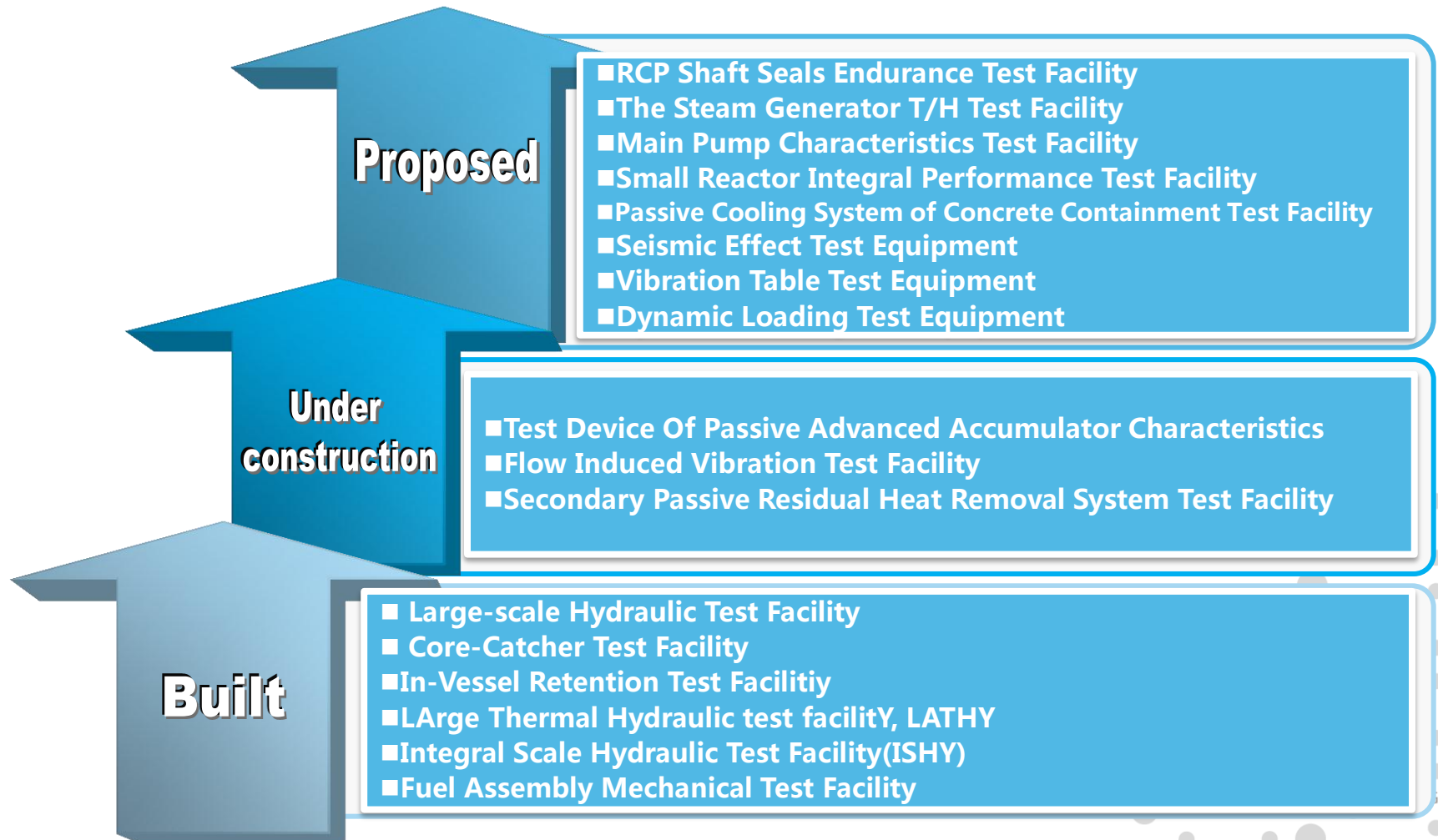
- CGN's advanced STEP™ series fuel assembly development
- CGN's advanced Zircalloy CZ™ development
- Nuclear fuel performance codes development, *National Science and Technology Major Project of China National Energy Administration*
- Accident tolerant fuel R&D
- New concept fuel research



1. Brief introduction of R&D in CGN

□ Research infrastructure of CGN

Main test platforms



1. Brief introduction of R&D in CGN

□ Research infrastructure of CGN (cont.)



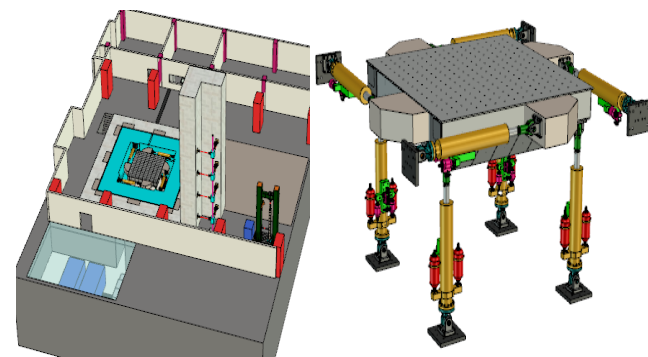
Large-scale Hydraulic Test Facility



Large thermal hydraulic test facility, LATHY



Integral Scale Hydraulic Test Facility, ISHY



Seismic Effect Test Facility

1. Brief introduction of R&D in CGN

□ Research infrastructure of CGN (cont.)



New fuel assembly mechanical and hydraulic test facilities



Material impact test machine



Creep and rupture strength test machine



LOCA high temperature oxidation and quench simulation test facility

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2. ATF related activities in China

□ International meeting participation

- OECD-NEA “1st International Meeting on Increased Accident Tolerance of Fuels for LWRs”, Paris, France, 10-12 December, 2012
- OECD-NEA “2nd International Meeting on Increased Accident Tolerance of Fuels for LWRs”, Paris, France, 28-29 October 2013
- China-US Civil Nuclear Energy Cooperation, Action Plan 6th Joint Technical working groups meeting, Xi'an, China, August 2013
- China-US Civil Nuclear Energy Cooperation, 2nd Steering Committee Meeting, Washington DC, US, April 2014



中广核 CGN

善用自然的能量
Natural Energy Powering Nature

Current status of fuel R&D

Nuclear Fuel R&D Center
China General Nuclear Power Corporation

OECD-NEA Meeting on Increased Accident Tolerance
of Fuels for LWRs, Paris, France
28-29 October 2013

中广核 CGN

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CGN' s Vision for Accident Tolerant Fuel Development Collaboration

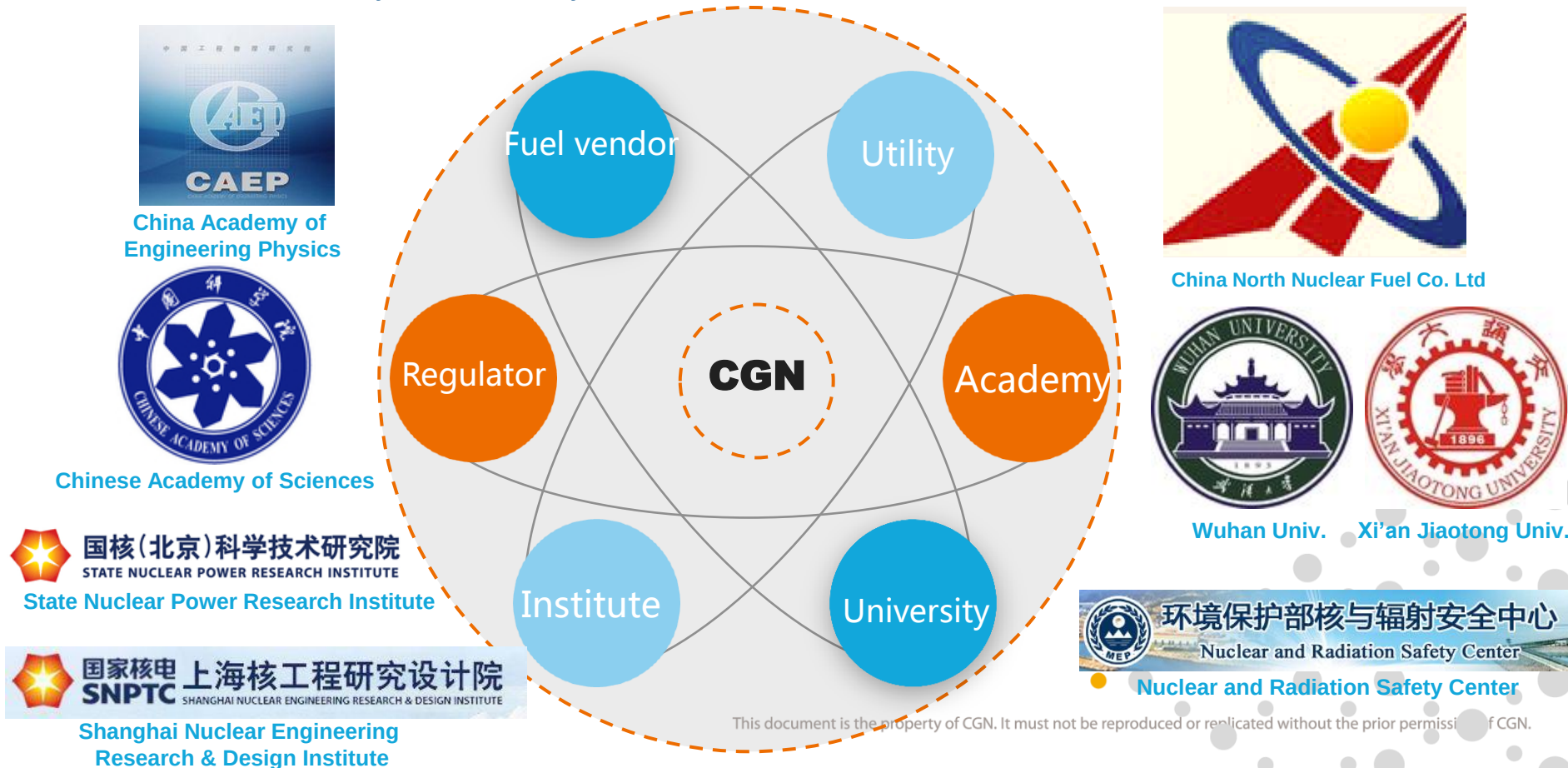
Nuclear Fuel R&D Center
China General Nuclear Power Corporation

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28-29 October 2013

2. ATF related activities in China

□ ATF development union

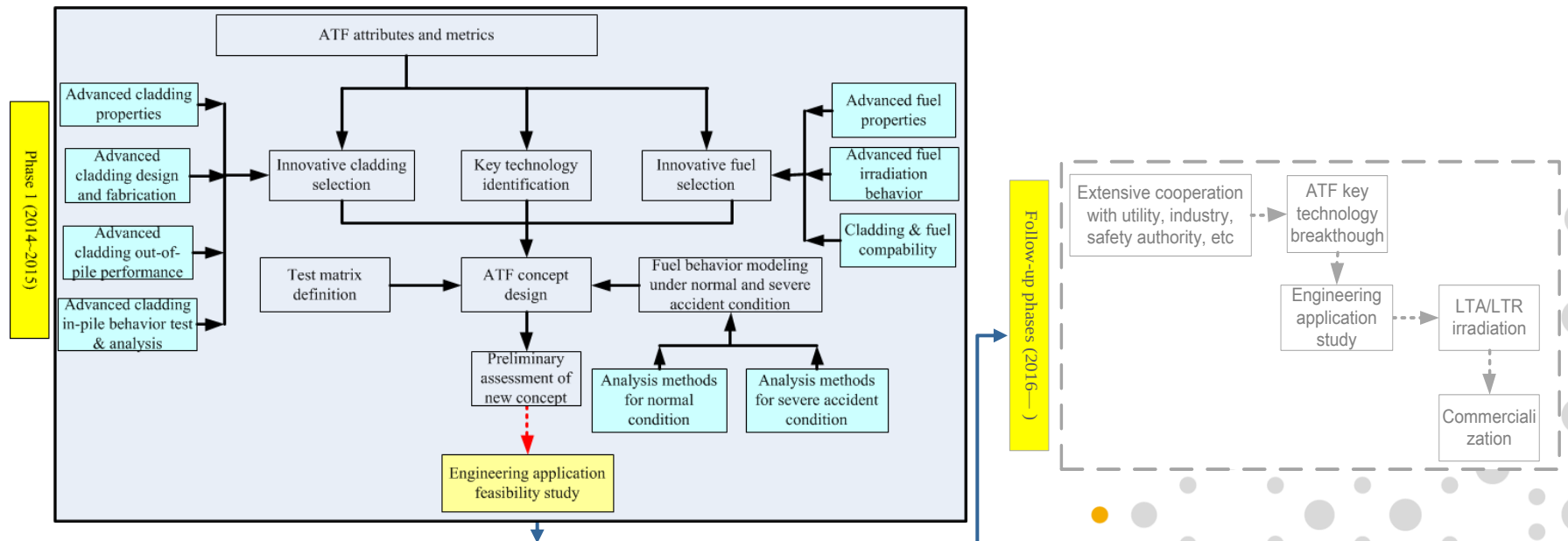
- The ATF development union has been established to promote ATF R&D in China, led by CGN and with extensive domestic superior organizations participated in, including vendor, utility, regulator, institute, university and academy.



2. ATF related activities in China

□ ATF research program

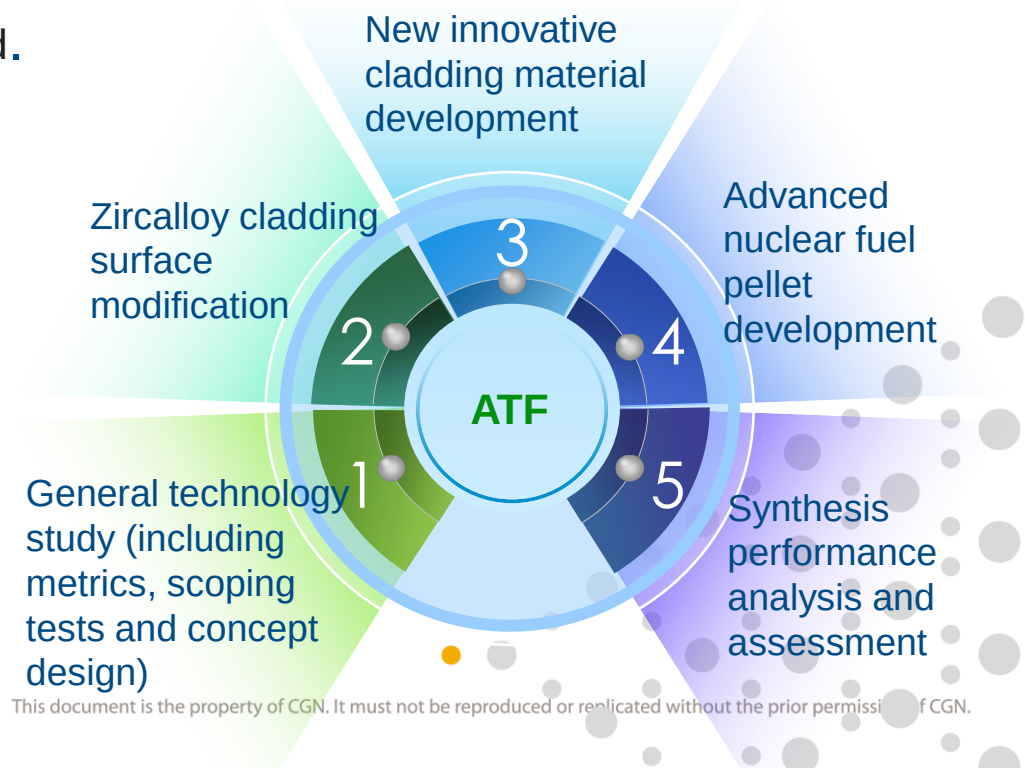
- Initiated by China National Energy Administration, the Chinese national ATF R&D strategic development plan is being conducted by CGN.
- Preliminary research on key technology of ATF has been launched in CGN, funded by CGN Science & Technology Innovative Program.



2. ATF related activities in China

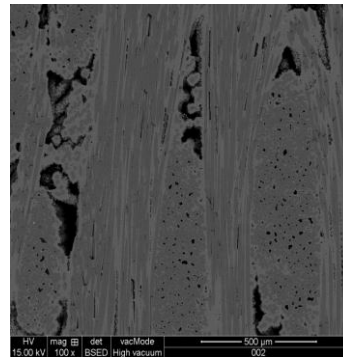
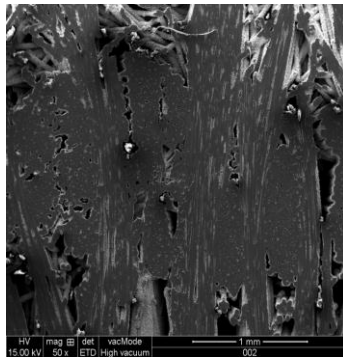
□ ATF research program (cont.)

- Research on key technology of ATF, *National Science and Technology Major Project of China National Energy Administration* (pending).
 - Initiated by CGN, over 10 domestic organizations participate in.
 - Total budget — RMB 240 million.
 - Five sub-projects were proposed.



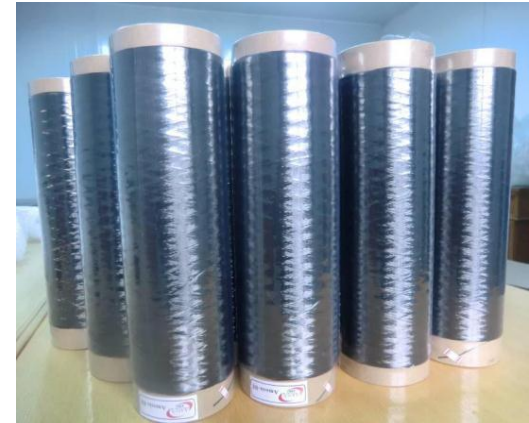
2. ATF related activities in China

□ SiC ceramic cladding development



■ SiC composite

Shanghai Institute of Ceramics
Chinese Academy of Sciences

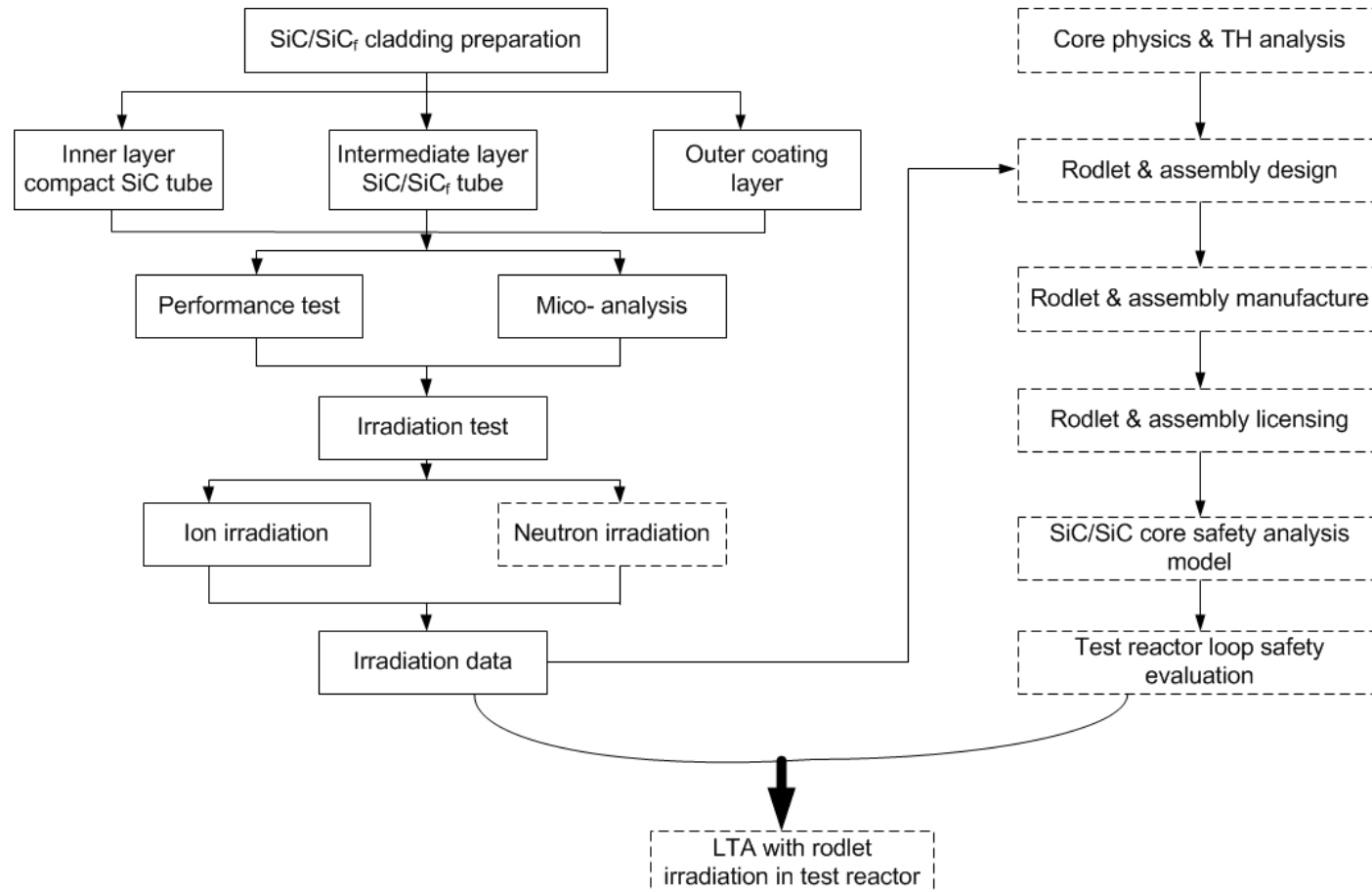


■ SiC/SiC_f composite tube



2. ATF related activities in China

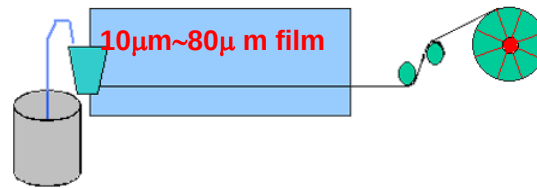
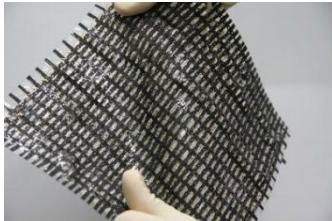
□ SiC ceramic cladding development (cont.)



2. ATF related activities in China

□ MAX phase material development

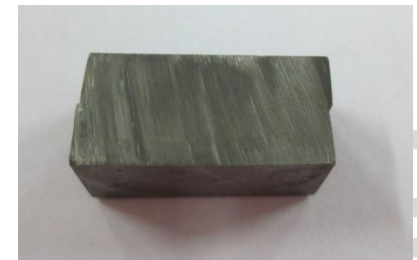
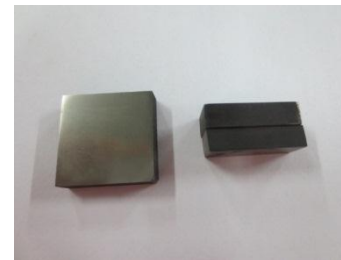
Ningbo Institute of Materials Technology and Engineering (NIMTE) of the Chinese Academy of Sciences (CAS),



Forming process



Irradiation behavior study

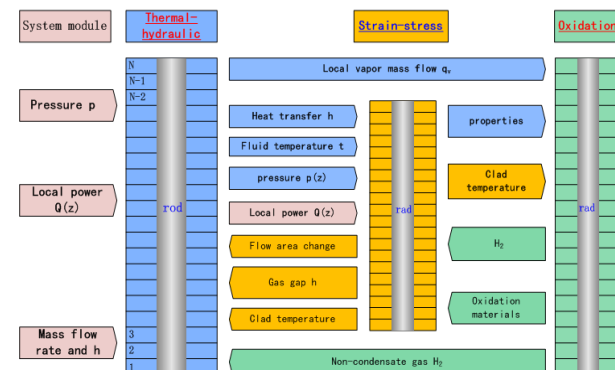
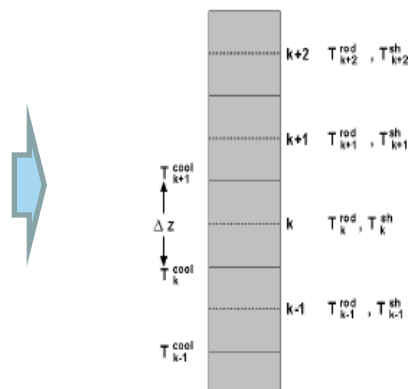
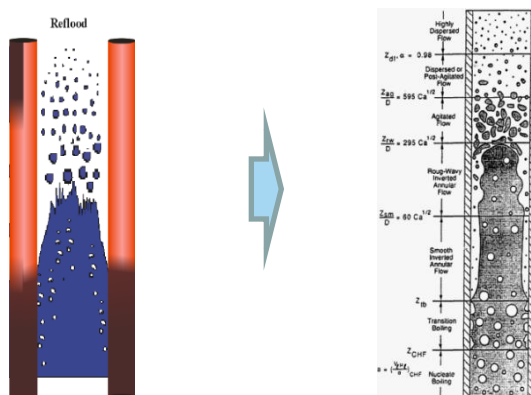


Joint technology

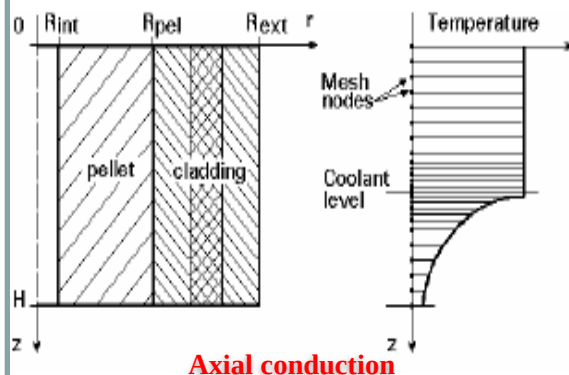
2. ATF related activities in China

❑ Fuel behavior analysis under accident condition

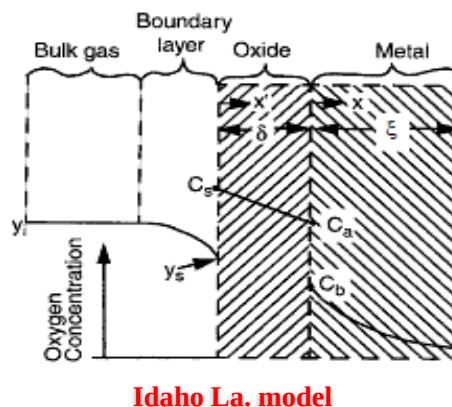
Xi'an Jiaotong Univ.



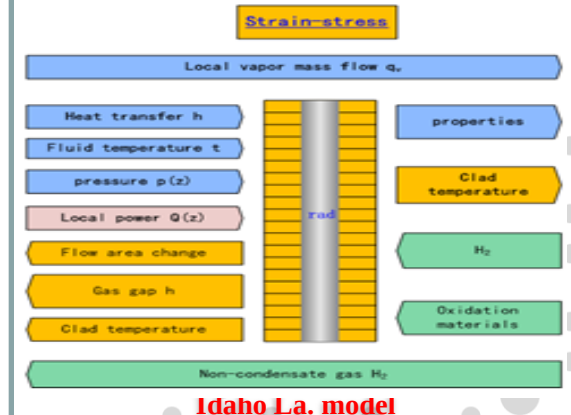
Conduction model



Oxidation model



Stress model



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3. Summary

- Under the background of international Accident Tolerant Fuel research, China has launched the national ATF R&D project, initiated by CGN and with extensive domestic superior organizations participated in;
- Existing or under construction research facilities and abilities in China will contribute to the implementation of ATF R&D activities;
- CGN is of great interest to ATF development, and international collaboration would be very beneficial.

Thank you for your attention