

Update of Accident Tolerant Fuel R&D status in China

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

17-18 September, 2015
4th meeting of OECD/NEA EGATFL, Villigen

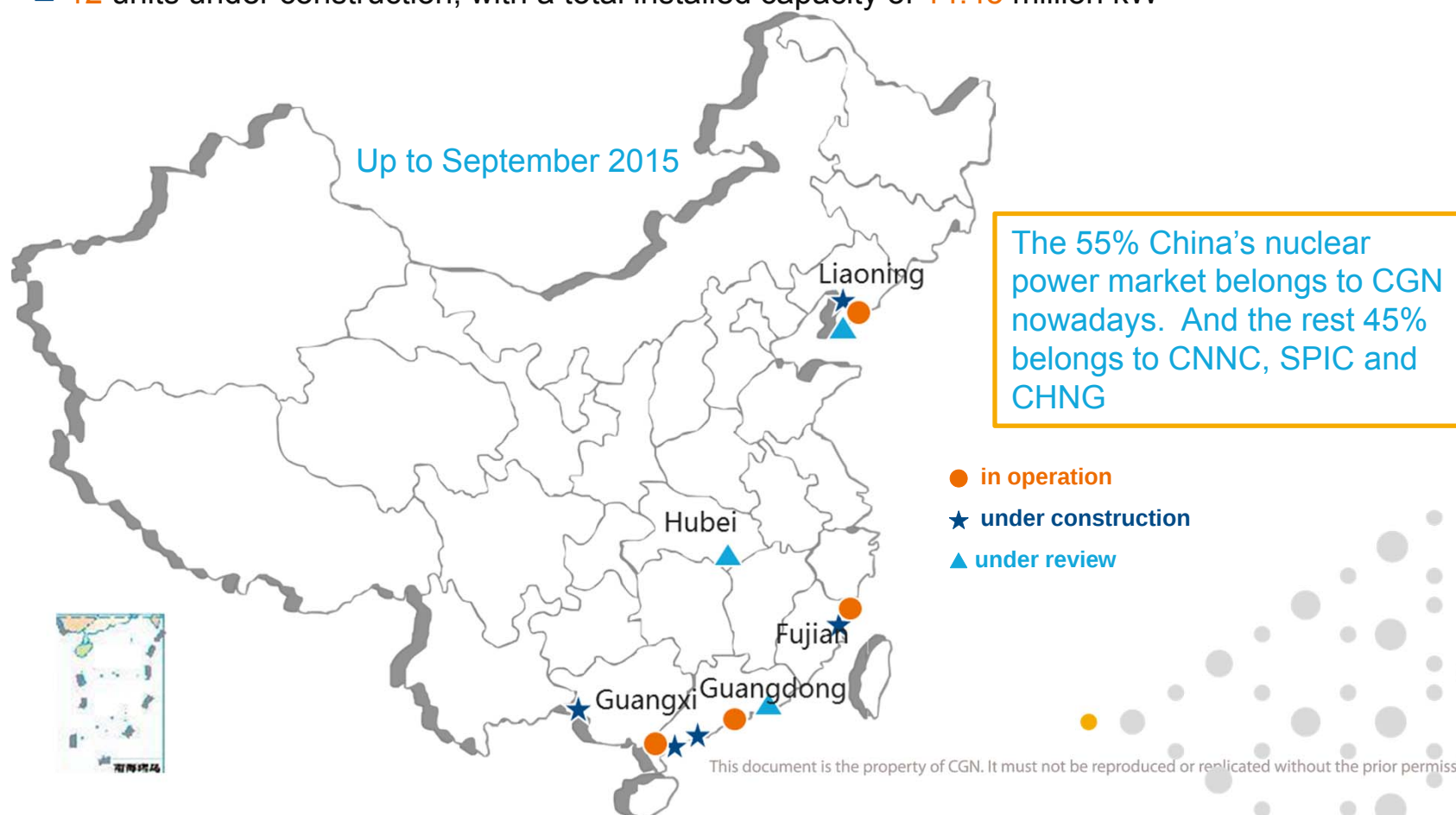
Contents

1. Brief introduction of CGN
2. Updated ATF development programs in China
3. Updated ATF research facilities in CGN
4. Updated research activities
5. Summary

1. Brief introduction of CGN

□ CGN nuclear power supply

- 14 units in operation, with a total installed capacity of 14.92 million kW
- 12 units under construction, with a total installed capacity of 14.45 million kW



Contents

1. Brief introduction of CGN
2. Updated ATF development programs in China
3. Updated ATF research facilities in CGN
4. Updated research activities
5. Summary

2. Updated ATF development programs in China

■ Research of ATF in China: *National Science and Technology*

Major Project / Strategic Research Project of CGN.

- ✓ Leading by CGN, over 15 domestic organizations participate in.
- ✓ Total funding more than million dollar (2015-2019 , phase I).
- ✓ Five sub-projects were proposed.

2. Updated ATF development programs in China



国家能源局
National Energy Administration

Research on key technology of ATF

National Science and Technology Major
Project , 5 Years

- *General technology study*
- *Zircalloy cladding surface modification*
- *New innovative cladding material development*
- *Advanced nuclear fuel pellet development*
- *Synthesis performance analysis and assessment*

中广核 CGN

中国广核集团有限公司
China General Nuclear Power Corporation

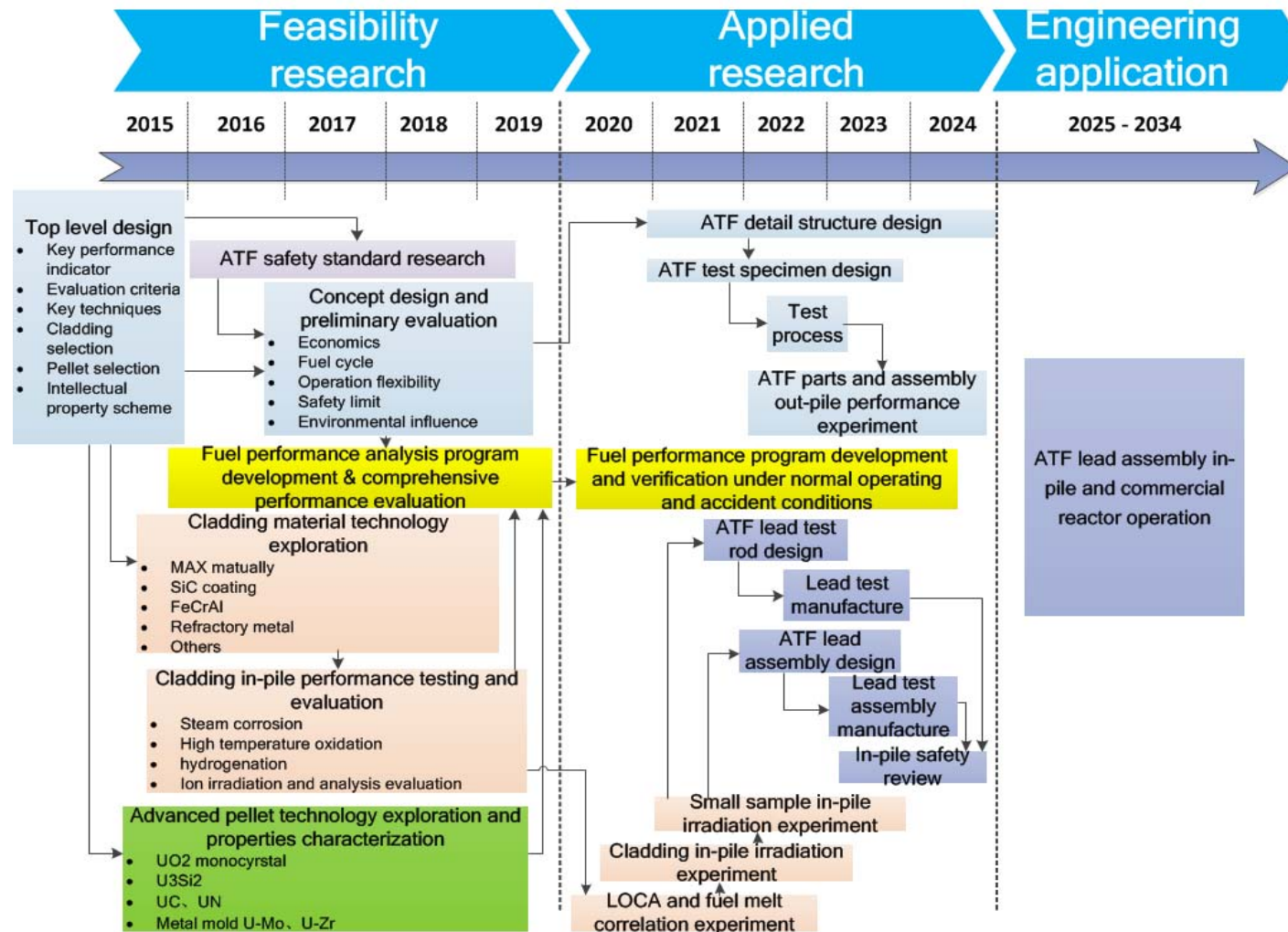
Research on base properties of ATF

The Strategic Research Project of CGN
2 Years

- *Metrics, Scoping tests, Concept design*
- *Advanced ODS alloys cladding, SiC cladding, Surface modification Zr cladding*
- *Enhanced UO₂ pellets, FCM pellets*
- *Simulation irradiation test and performance analysis*

2. Updated ATF development programs in China

■ Three Steps of ATF R&D in China



2. Updated ATF development programs in China

■ Members of ATF R&D group in China

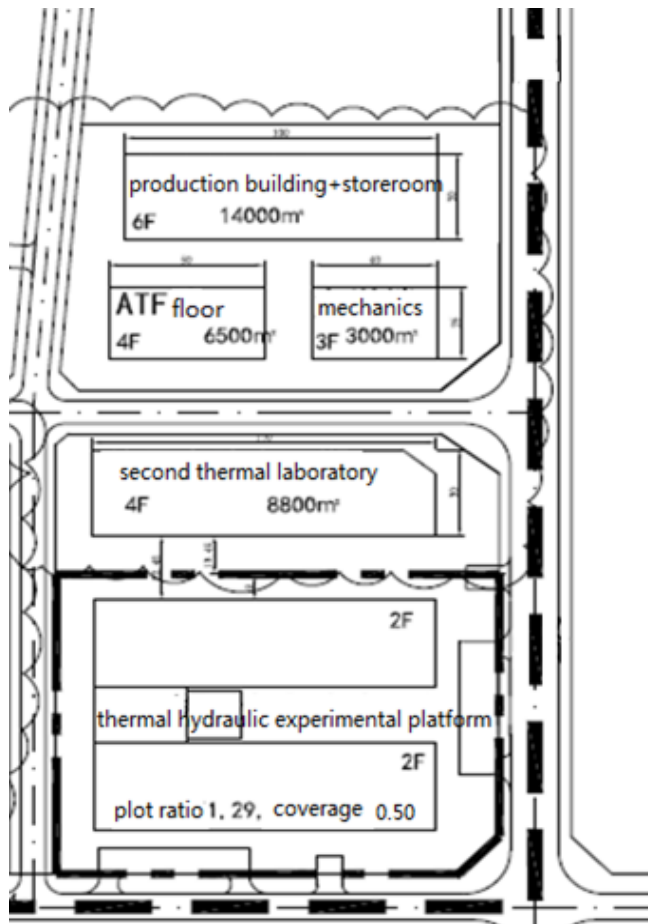


Contents

1. Brief introduction of CGN
2. Updated ATF development programs in China
3. **Updated ATF research facilities in CGN**
4. Updated research activities
5. Summary

3. Updated ATF research facilities in CGN

□ CGNPC longgang laboratory



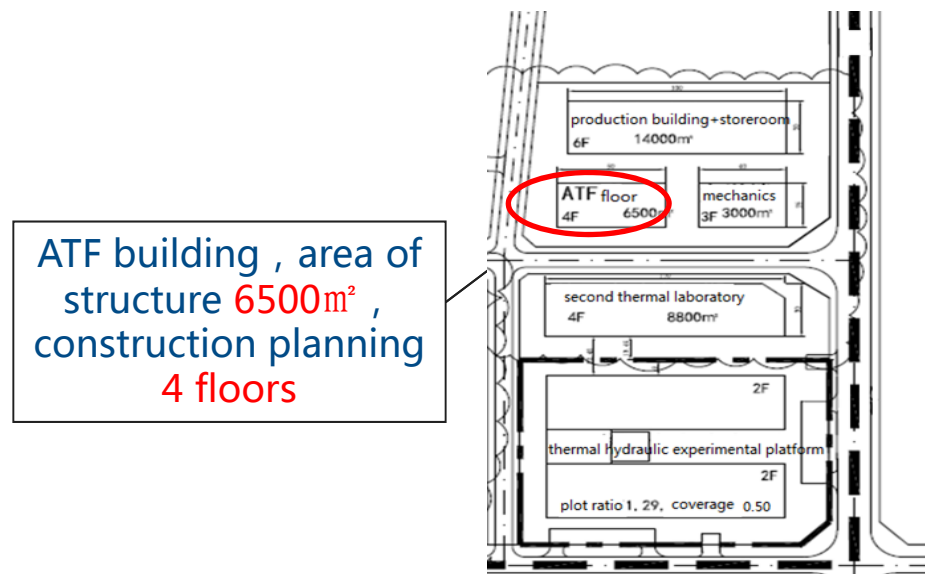
- Large thermal hydraulic comprehensive test apparatus
- Large hydraulic test device
- Core melt IVR experiment device
- Core supply test apparatus
- Entirety hydraulic proportion simulation test device
- Fuel assembly mechanical test device
- ATF out-pile property test device (under construction)
- Seismic effect test apparatus (under construction)
- Reaction system test device (under construction)
- Small reactor overall performance test device (under construction)

Construction completed

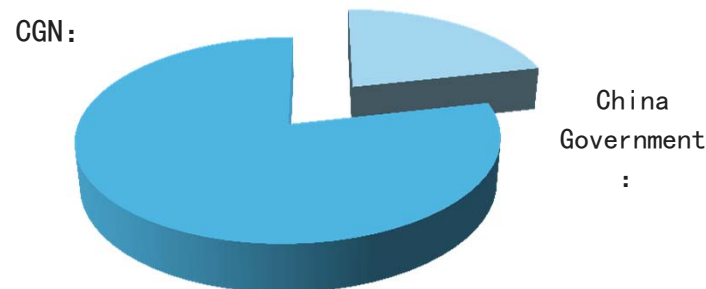


3. Updated ATF research facilities in CGN

□ ATF laboratory construction



Equipment investment by 2015



Cladding physical and chemical laboratory

Cladding material metallographic sample

Cladding material heat treatment

Cladding material corrosion property

Cladding material mechanical property

Accident condition performance

Cladding material microstructure analysis

Cladding material thermal physical property analysis

Eight function laboratories

3. Updated ATF research facilities in CGN

□ Research facilities of CGN



Materials internal pressure creep and fatigue test facilities



LOCA high temperature oxidation and quenching simulation test facility



XRD

3. Updated ATF research facilities in CGN

□ Research facilities of CGN



ZEISS MERLIN SEM



FEI TALOS F200X TEM

3. Updated ATF research facilities in CGN

□ Research facilities of CGN



Integrated thermal analyzer



Laser thermal conductivity meter



Thermal expansion instrument

3. Updated ATF research facilities in CGN

□ Research equipments of CGN-CQU Joint Laboratory

■ The research facilities and equipment:

- Advanced TEM, 3D atom probe;
- Advanced mechanical alloying system.



FEI TITAN TEM



3D atom probe

3. Updated ATF research facilities in CGN

□ Research equipments of CGN-CAEP Joint Laboratory

■ The research facilities and equipment:

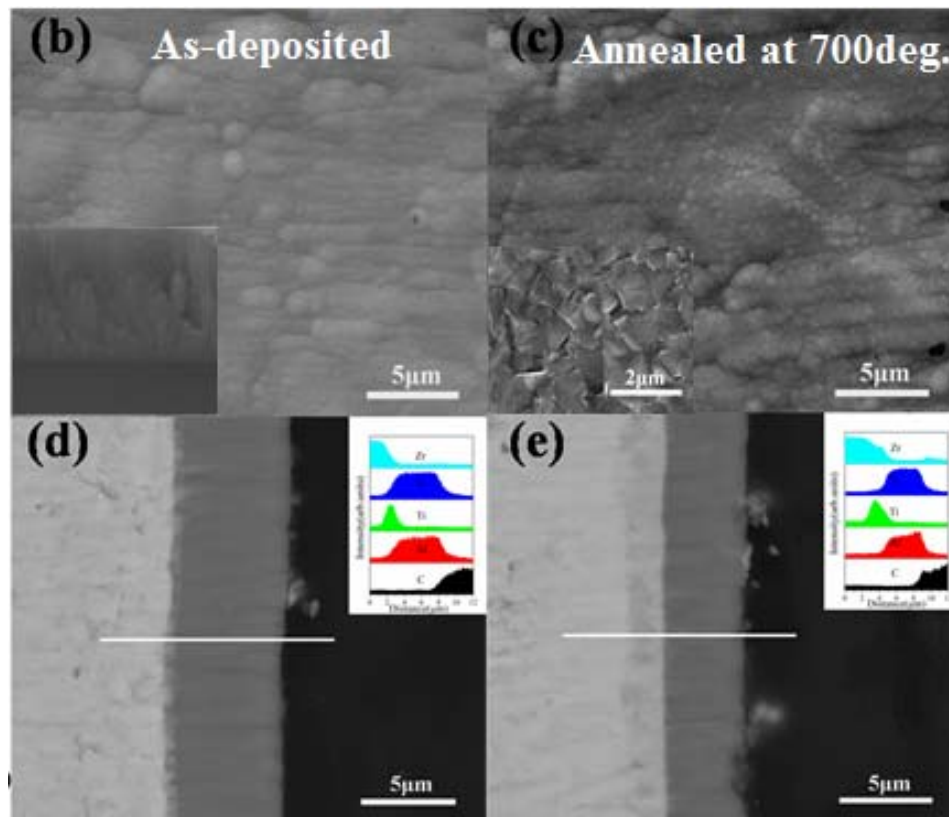
- Advanced TEM, SEM;
- Advanced research reactor;
- Large-scale hot cell;
- Hot pressure furnace;
- Spark plasma sintering furnace;
- Comprehensive surface analysis system.

Contents

1. Brief introduction of CGN
2. Updated ATF development programs in China
3. Updated ATF research facilities in CGN
4. Updated research activities
5. Summary

4. Updated research activities

□ MAX phase coating development

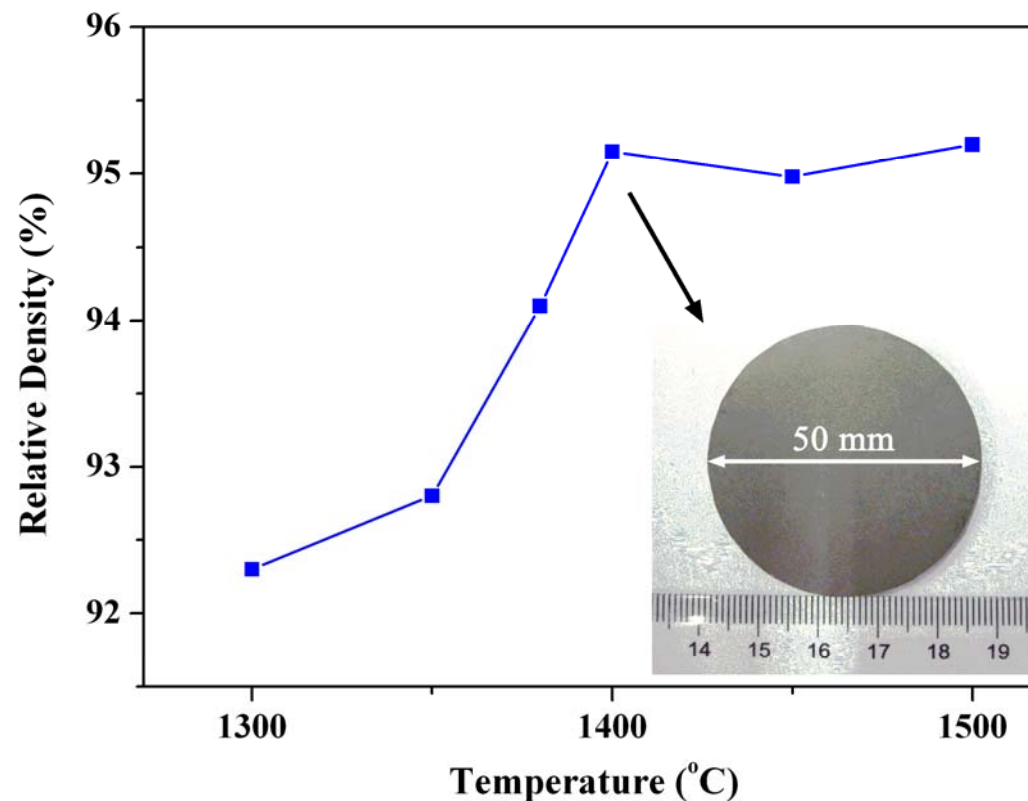


■ SEM photo of V-Al-C coating microstructure on Zr surface.

■ The research was launched by SPIC, funding supported by CGN and China government.

4. Updated research activities

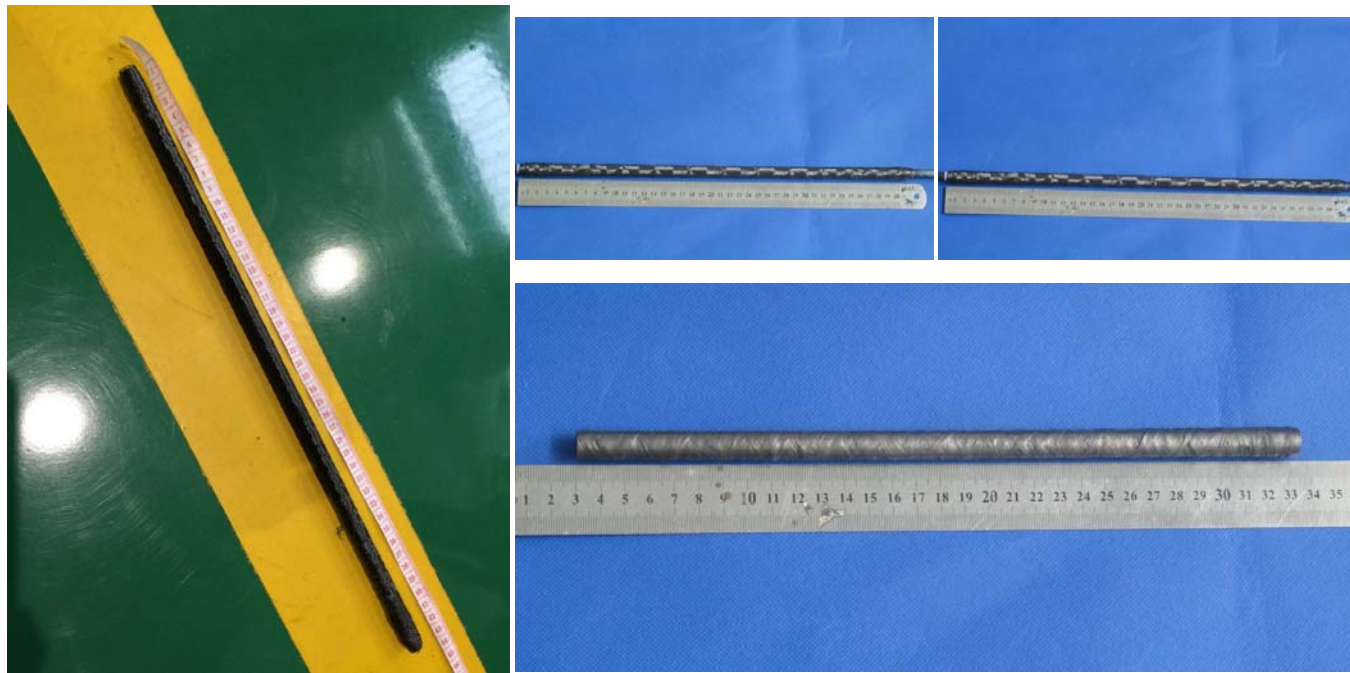
□ MAX phase cladding material development



- The relative sintered density versus sintering temperature for Ti-Si(Al)-C
- The sample were prepared and tested by CGN-CAEP joint laboratory, funding supported by CGN and China government.

4. Updated research activities

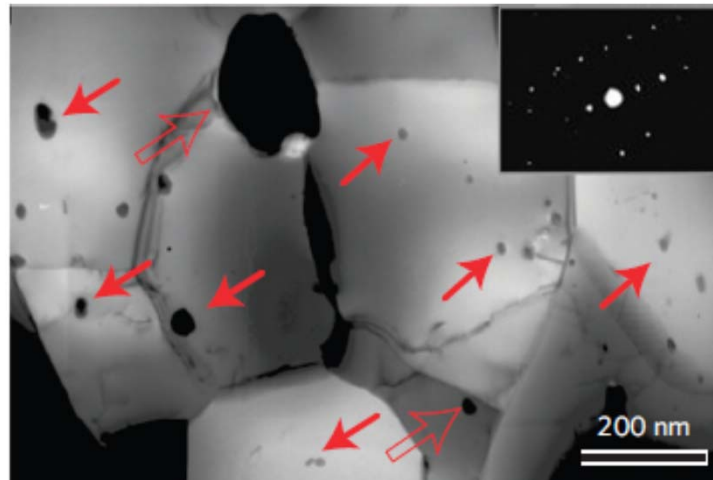
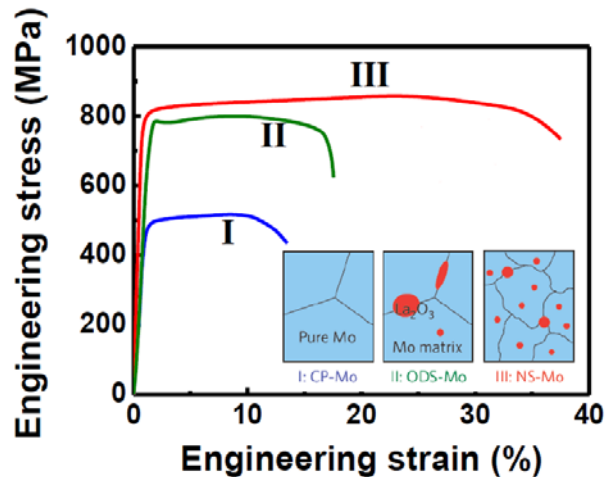
□ SiC/SiC composite material cladding development



- The SiC/SiCf composite tube manufactured by Northwestern Polytechnical University, funding supported by CGN.

4. Updated research activities

Mo-alloy cladding development



- The tube was prepared by NS-Mo.
- The sample were supplied by Jinduicheng Molybdenum CO. ,LT, supported by CGN.

4. Updated research activities

□ FCM Fuel development



■ SiC Matrix of FCM Fuel

■ The matrix without real TRISO fuel particles is manufactured by CGN-CAEP joint laboratory.

■ The TRISO particles with U_3Si_2 and UN kernel are developing in Tsinghua University, supported by CGN.

4. Updated research activities

□ U-Mo Fuel development

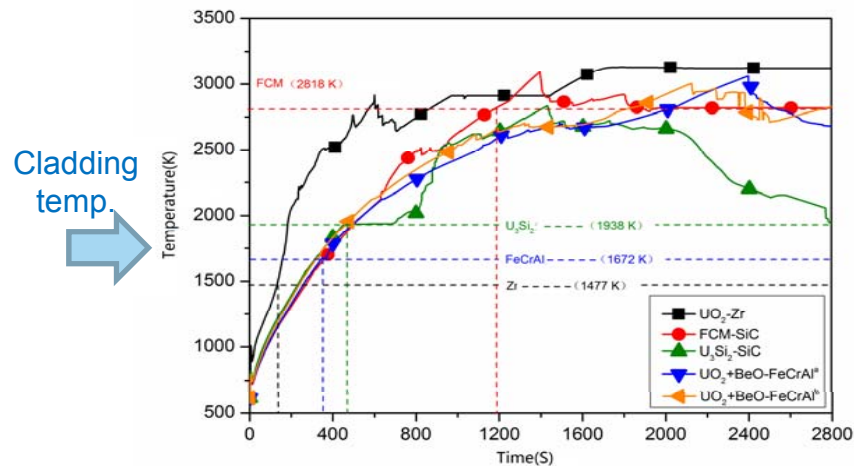
- The project is on going, CNNC and SPIC are developing the manufacturing technology.
- The project funding is supported by CGN and China government.

4. Updated research activities

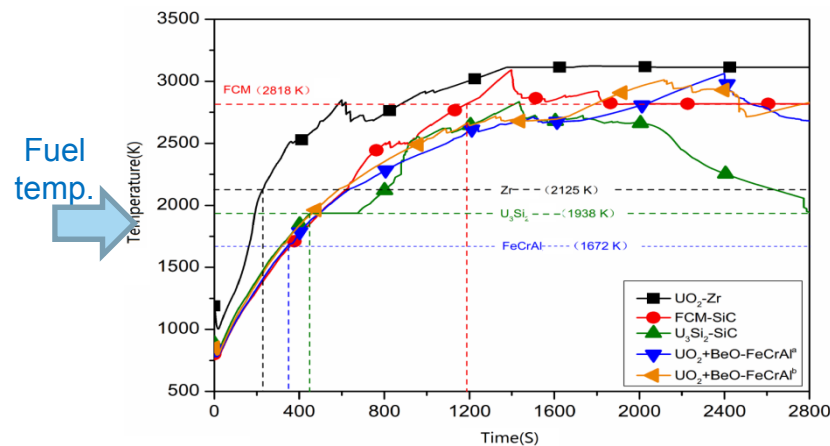
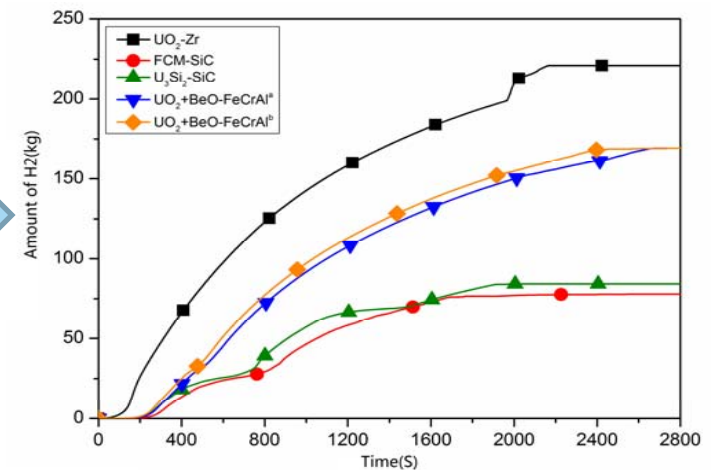
□ ATF conceptual design and preliminary analysis

CGN & Xi'an Jiaotong University

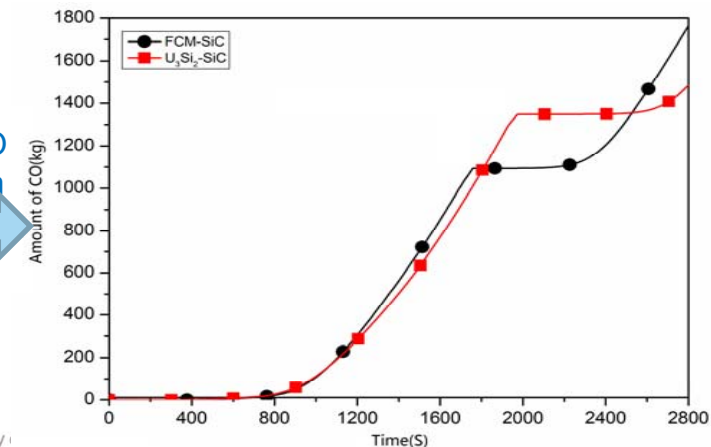
■ LOCA performance



In-core hydrogen generation →



In-core CO generation →

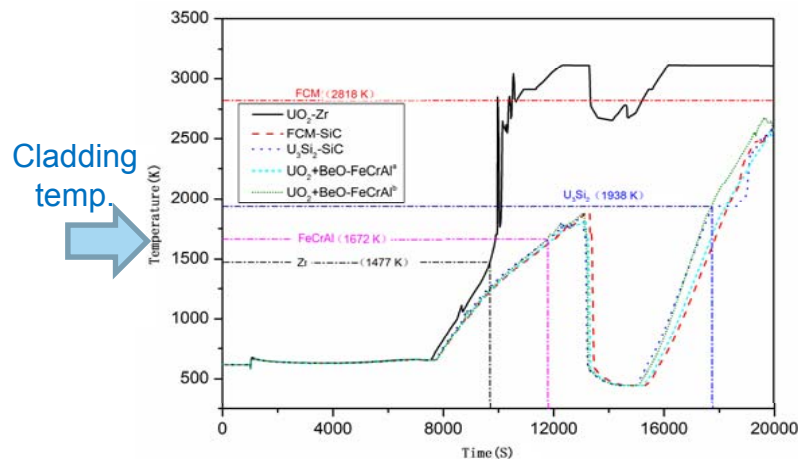


4. Updated research activities

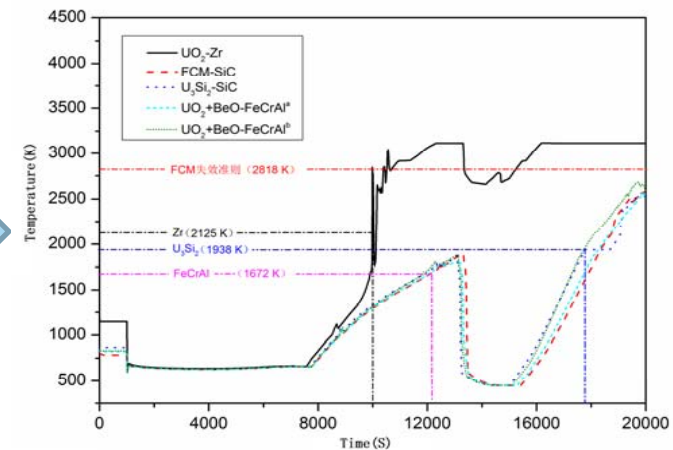
□ ATF conceptual design and preliminary analysis

CGN & Xi'an Jiaotong University

■ SBO performance



Fuel temp. →



Failure time

	UO ₂ -Zr	FCM-SiC	U ₃ Si ₂ -SiC	UO ₂ +BeO-FeCrAl ^a	UO ₂ +BeO-FeCrAl ^b
Event	Time(S)				
Cladding temp. to 1477K	8716.0*	9982.0	9756.0	9925.0	9811.0
Cladding temp. to 1672K	8907.0	11074.0	10887.0	11048.0*	10843.0*
Pellet temp. to 1938K	8987.0	17194.0	16916.0*	17269.0	16744.0
Pellet temp. to 2818K	8987.0	>19000.0*	>19000.0	>19000.0	>19000.0

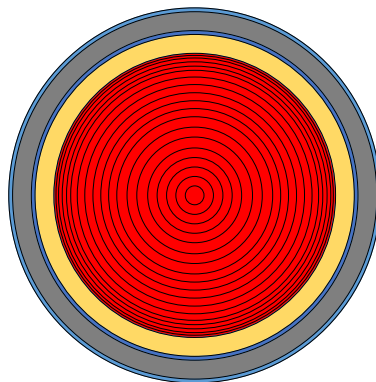
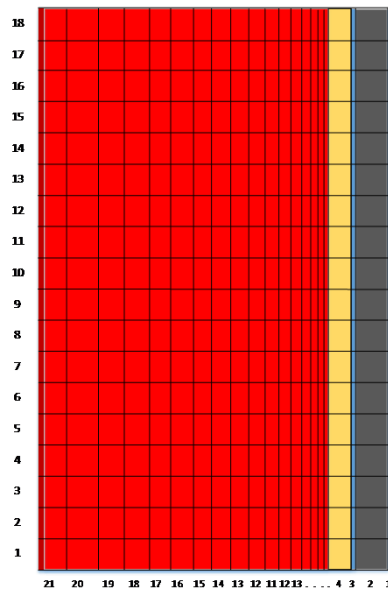
a:cladding thickness is 0.57mm, b:cladding thickness is 0.45mm

*failure time

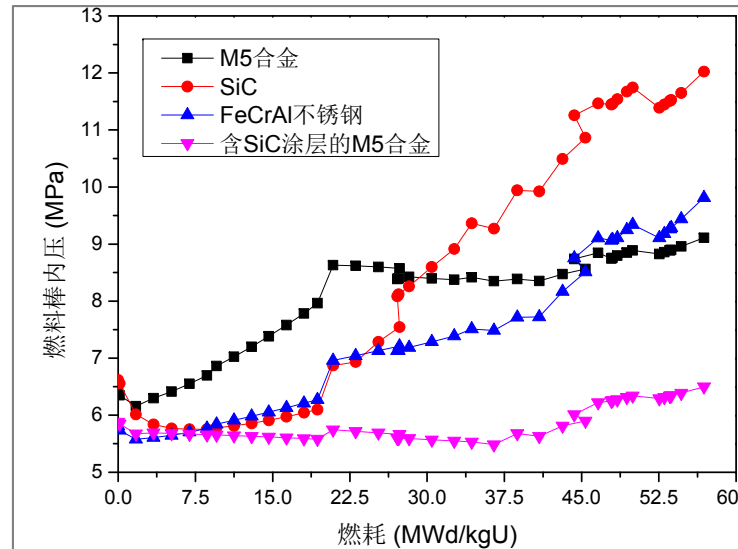
The first failure ATF system (UO₂+BeO-FeCrAl^b) is 2000s later than the standard UO₂-Zr system.

4. Updated research activities

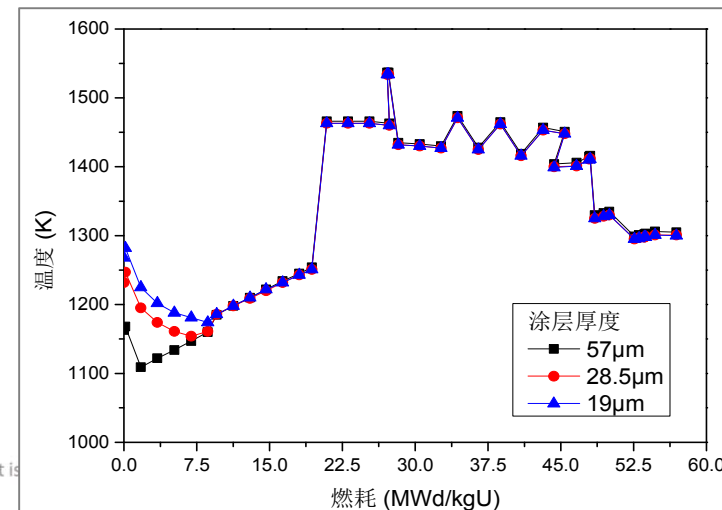
□ ATF fuel element steady analysis



The impact of the coating thickness on pellet center temperature

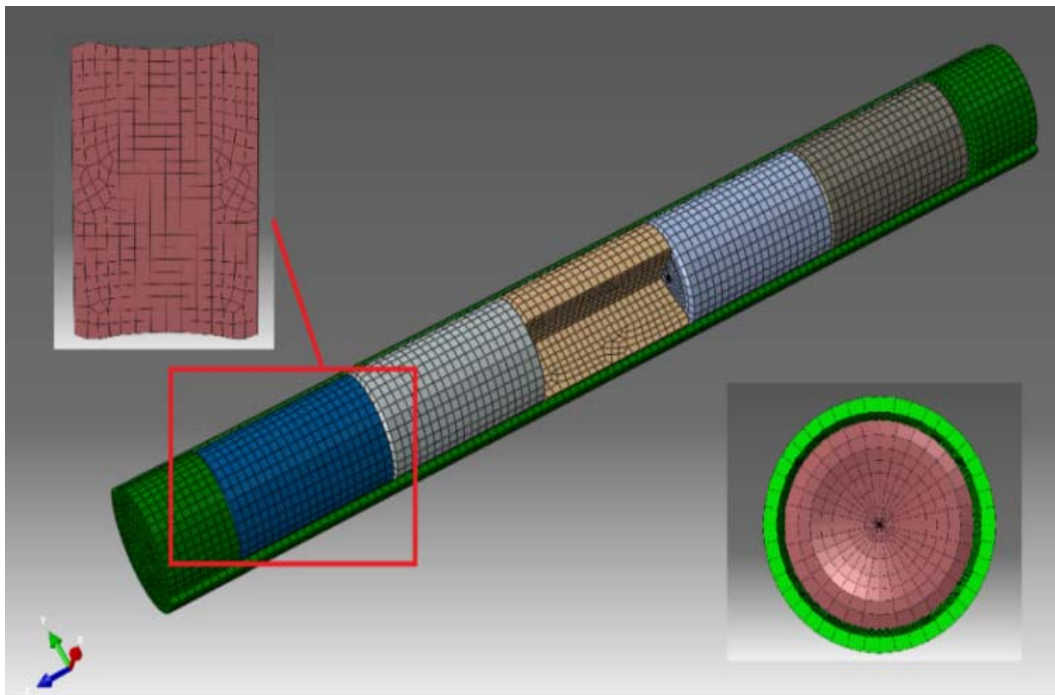


The pressure of fuel rods changes along with the burnup.

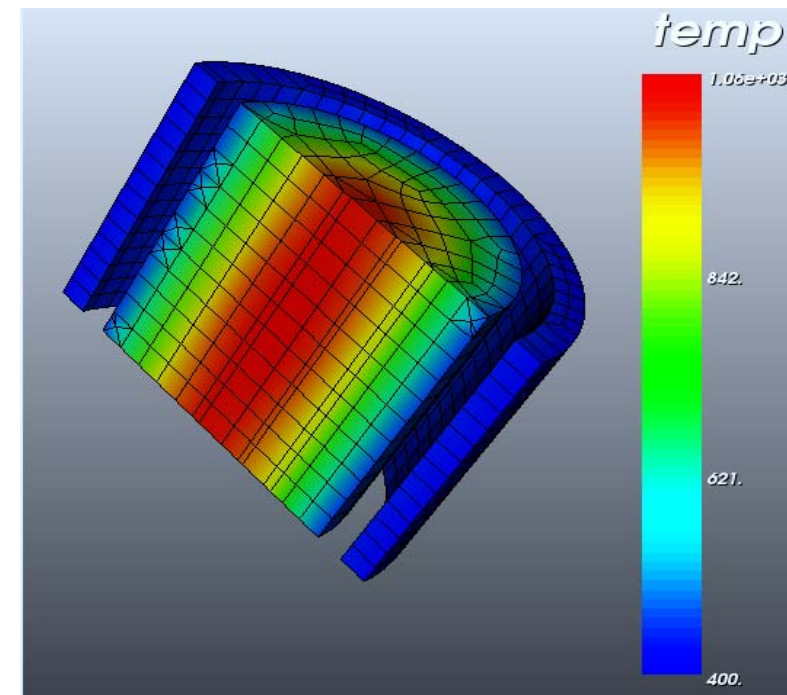


4. Updated research activities

□ ATF fuel element 3D analysis model development



■ Fuel element finite model (Trelis)



■ Fuel element heat transfer analysis results (Paraview)

Contents

1. Brief introduction of CGN
2. Updated ATF development programs in China
3. Updated ATF research facilities in CGN
4. Updated research activities
5. Summary

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- According to China's policy, R&D key projects must meet the needs of market, and dominated by the company which support the funding. So CGN led the China's ATF R&D group. The industry's core companies, such as CNNC, SPIC, CAEP and CAS have been join in the group.
- A new ATF laboratory building is under construction. Research facilities and instruments will be operated at the end of 2017. CGN plans to establish a national experiment platform by the ATF laboratory.
- The research group has obtained some achievements on the study of coating, SiC/SiC cladding, Mo alloy cladding, MAX phase material, FCM, ATF conceptual design and preliminary analysis.

Thank you for your attention