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

- **About China General Nuclear**
  - GNPS
    - start from a high level
    - construction with loans, repayment by electricity sales, operation through joint venture
  - LNPS Phase I
    - self-reliant development of nuclear power per international standards
  - LNPS Phase II, HNPS, NNPS, YNPS, FNPS, CPR1000
  - TNPS (3G technology — EPR)
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  - realizing “four self-reliance” capabilities
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1. Brief introduction of R&D in CGN

- CGN nuclear power supply
  - 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

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

- **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)

  - Year: 2007, Expenditure: 3.8
  - Year: 2008, Expenditure: 5.2
  - Year: 2009, Expenditure: 8.8
  - Year: 2010, Expenditure: 9.8
  - Year: 2011, Expenditure: 12.6
  - Year: 2012, Expenditure: 14.7
  - Year: 2013, Expenditure: 15.5
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.

  - **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

- RCP Shaft Seals Endurance Test Facility
- The Steam Generator T/H Test Facility
- Main Pump Characteristics Test Facility
- Small Reactor Integral Performance Test Facility
- Passive Cooling System of Concrete Containment Test Facility
- Seismic Effect Test Equipment
- Vibration Table Test Equipment
- Dynamic Loading Test Equipment

- Test Device Of Passive Advanced Accumulator Characteristics
- Flow Induced Vibration Test Facility
- Secondary Passive Residual Heat Removal System Test Facility

Built

- Large-scale Hydraulic Test Facility
- Core-Catcher Test Facility
- In-Vessel Retention Test Facility
- LArge Thermal Hydraulic test facilItY, LATHY
- Integral Scale Hydraulic Test Facility(ISHY)
- Fuel Assembly Mechanical Test Facility

Under construction

- Proposed
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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- **International meeting participation**
  - OECD-NEA “1st International Meeting on Increased Accident Tolerance of Fuels for LWRS”, Paris, France, 10-12 December, 2012
  - 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
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

- SiC/SiCf composite tube
2. ATF related activities in China

- **SiC ceramic cladding development (cont.)**

  - SiC/SiC cladding preparation
    - Inner layer compact SiC tube
    - Intermediate layer SiC/SiC tube
    - Outer coating layer
      - Performance test
      - Micro-analysis
      - Irradiation test
        - Ion irradiation
        - Neutron irradiation
      - Irradiation data
    - LTA with rodlet irradiation in test reactor

  - Core physics & TH analysis
    - Rodlet & assembly design
    - Rodlet & assembly manufacture
    - Rodlet & assembly licensing
      - SiC/SiC core safety analysis model
      - Test reactor loop safety evaluation
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**

- Axial conduction

**Oxidation model**

- Idaho L.a. model

**Stress model**

- Idaho L.a. model
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- 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