SFR systems R&D activities

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Chair of SFR-SSC

GIF-INPRO Interface meeting
26-27 March 2018,
IAEA HQ, Vienna
System Integration & Assessment Project
System Integration & Assessment Project

Members

- France (CEA)
- US (USDOE)
- Japan (JAEA)
- Korea (KAERI)
- EURATOM (JRC)
- China (CIAE)
- RF (Rosatom)

Project Objectives

- Integration of the results of R&D Projects
- Performance of design and safety studies
- Assessment of the SFR System against the goals and criteria set out in the Gen IV Technology Roadmap
System Integration & Assessment Project

Integration Role

Specific tasks have been developed and refined

- **Identify** Generation-IV SFR Options
  - General system options
  - Specific design tracks
  - Contributed trade studies

- **Maintain comprehensive list of R&D needs**

- **Review** Generation-IV SFR Technical Projects

- Unlike the technical Projects, based on synthesis of results produced by other Projects
Current SFR System Options

- **System Option #1 - Loop Configuration SFR**
  - Design Track #1a – JSFR
    » Contributor – JAEA

- **System Option #2 – Pool Configuration SFR**
  - Design Track #2a – KALIMER (PGSFR)
    » Contributor – KAERI
  - Design Track #2b - ESFR
    » Contributor – Euratom
  - Design Track #2c - BN-1200
    » Contributor - ROSATOM

- **System Option #3 - Small Modular SFR**
  - Design Track #3a – AFR-100
    » Contributor – USDOE

- **Base on the result of self-assessment for BN-1200 (Russia), members decided BN-1200 as Design Track #2c (Contributor – ROSATOM).**

- **CFR1200 (China) concept is under preparation for inclusion as Design Tracks into System Option #2.**
Gen IV SFR System Options and Design Tracks

Loop
- JSFR

Pool
- ESFR
- KALIMER

Small Modular
- AFR-100
**BN-1200 (Russia) (new design track)**

- The BN-1200 is designed as a commercial large size nuclear power unit with pool-type sodium-cooled fast reactor using a traditional steam-water tertiary circuit.
- BN-1200 has enhanced safety based on maximal application of inherent safety features and passive safety systems that allows to meet safety requirements set for the 4th generation reactors.
- Application of some innovative decisions, in particular integral steam generators, simple refuelling system etc, decreases strongly cost of the power unit making it competitive with other energy sources.

- IHX; 2,3 – main and guard vessel; 4 – supporting structure; 5 – inlet plenum; 6 – core catcher; 7 – core; 8 – pressure pipeline; 9 – MCP-1; 10 – refueling mechanism; 11 – CRDM; 12 – rotating plugs
CFR-1200 (China) *(candidate for design track)*

- CFR-1200 is a 1200MWe pool type sodium-cooled fast reactor.
- MOX fuel and ODS cladding material will be used based on the design goals.
- Passive features, including passive shutdown and passive heat removal, will both be considered for safety.
- For the power conversion system, some R&D of Super-CO2 conversion will also be carried out in spite of water-steam conversion as the first choice.
Advanced Fuel Project
Advanced Fuel Project

Members

- France (CEA)
- US (USDOE)
- Japan (JAEA)
- Korea (KAERI)
- EURATOM (JRC)
- China* (CIAE)
- RF *(Rosatom)

* ROSATOM and CIAE joined the SFR AF Project from October 2015.

Project Objectives

- Selection of high burn-up MA bearing fuel(s), cladding and wrapper withstanding high neutron doses and temperatures.
- Candidates:
  - Driver fuels (Oxide, Metal, Nitride & Carbide), Inert Matrix fuels & MA Bearing Blankets
  - Core materials: Ferritic/Martensitic & ODS steels
- Scopes:
  - Fabrication
  - Behavior under irradiation
Expected target schedule

- SFR Non-MA-bearing Driver Fuel Evaluation, Optimization & Demonstration
- MA-bearing Transmutation Fuel Evaluation, Optimization & Demonstration
- High-burnup Fuel Evaluation, Optimization & Demonstration

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Global Actinide Cycle International Demonstration (GACID) Project
GACID Project

Members

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Project Objectives

To demonstrate, using Joyo and Monju, that FR’s can transmute MA’s (Np/Am/Cm) and thereby reduce the concerns of HL radioactive wastes and proliferation risks.
Overview of GACID Conceptual Scheme

[Original Plan]

➢ Objective: to demonstrate, using Joyo and Monju, that FR’s can transmute MA’s (Np/Am/Cm) and thereby reduce the concerns of HL radioactive wastes and proliferation risks.

➢ A phased approach in three steps.

➢ Material properties and irradiation behavior are also studied and investigated.

The Project is being conducted by CEA, USDOE and JAEA as a GIF/SFR Project, covering the initial 10 years since Sep. 27, 2007.
The followings have been conducted in GACID Project so far, in order to support the licensing of MA-bearing fuel irradiation test in Monju:

✓ material properties data acquisition
✓ MA-bearing fuel irradiation behavior modeling
✓ PIE data analyzing on irradiation test such as Superfact, Am-1 and AFC series
✓ preparation of Am and Cm feedstock source
✓ transportation of MA raw materials
✓ MA-bearing fuel sample fabrication tests, etc.
Termination of GACID Project

The final goal of GACID project is to utilize the Np/Am/Cm bearing fuel as Monju fuel subassembly scale in order to demonstrate the MA incineration capability of fast neutron reactors on an engineering scale.

Because there is no possibility of irradiation in Monju due to the decision of decommissioning of Monju and the final goal of GACID project can not be achieved, GACID PMB decided the followings in the previous PMB meeting dated June 19 this year:

- GACID Project will not be continued after the expiration date of PA (Sep. 27, 2017).
- SFR-SSC approved the termination of GACID on Sep. 26.
- GACID PMB was closed on Sep. 27, 2017.
Component Design & Balance Of Plant Project
CD&BOP Project

Members

- France (CEA)
- US (USDOE)
- Korea (KAERI)
- EURATOM (JRC)
- Japan (JAEA)

* ROSATOM and CIAE are under negotiation of participation.

Project Objectives

Research & Development on these systems;

- In-Service Inspection
- Repair
- Leak Before Break (LBB) Assessment
- Supercritical CO2 Brayton Cycle Energy Conversion
- Steam Generators
Project R&D Areas 2017-2021

1. Study of ISI&R technologies (ISI&R):
   Development of various innovative inspection technologies, transducers development and testing, waveguide development and testing, sodium wetting behavior, EC flowmeter for fuel assembly outlet flow measurement, CIVA code applications, under sodium viewing techniques development

   PHÉNIX, JOYO, MONJU, development of technology for component repair under sodium

2. Study of AECS technologies (AECS):
   Testing of small-scale compact diffusion-bonded heat exchangers, testing of small-scale S-CO$_2$ compressors, sodium-CO$_2$ interactions, CO$_2$ corrosion of various austenitic and ferritic steels, analyses of SFRs incorporating S-CO$_2$ Brayton cycles, plant dynamic analyses for SFRs with S-CO$_2$ cycles, sodium plugging of sodium-to-CO$_2$ heat exchanger sodium channels
Project R&D Areas 2017-2021

3. Study of sodium leakages and consequences (SL):
   Development of leak before break (LBB) assessment procedures, instrumentation to detect sodium leakage, consequence analysis (sodium fire and aerosols) and mitigation approaches. The creep-fatigue crack initiation and growth behavior in ferritic martensitic steels.

   Development in the field of sodium leakage detection is also an objective, with improvement of time response and limitation of false alarms. Better knowledge of sodium fire in order to limit its consequences and design the well appropriate mitigation systems.

4. Study of steam generators (SG):
   Development of steam generators including investigations of sodium-water reactions and development of advanced inspection technologies for a Rankine-type steam generator.

5. Study of sodium operation technology and new sodium testing facilities (O&TF):
   To share and/or development of sodium drainability, wetting, plugging, and purification, freezing and remelting, and to share the information of the existing and/or new sodium testing facilities
Safety & Operation Project
**S&O Project**

**Members**

- France (CEA)
- US (USDOE)
- Japan (JAEA)
- Korea (KAERI)
- EURATOM (JRC)
- China (CIAE)
- RF (Rosatom)

**Project Objectives**

- Analyses and experiments that support safety approaches and validate specific safety features
- Development and validation of computational tools useful for such studies
- Acquisition of reactor operation technology, as determined largely from experience and testing in operating SFR plants
Work Packages in SO project

- WP SO 1 – Methods, models and codes
- WP SO 2 – Experimental programs and operational experiences
- WP SO 3 – Studies of innovative design and safety systems
Objective

• The basic function of the refueling system is to transfer new fuel assembly to the core and transport spent fuel assembly to the cooling pool outside the reactor.

• During the transport process, the fuel assembly is exposed to different environment, may resulting in a decrease in heat transfer capacity.

• Once an accident occurs, the spent fuel assembly will be in the environment for a long time, and the adverse heat transfer condition will lead to the increase of the cladding temperature and even the damage.

• Therefore, it is necessary to obtain the maximum temperature of the cladding, by analyzing fuel assembly heat transfer conditions during transportation process.
Objectives:

- feasibility study of the finite element model of the ASTRID-like reactor structure with the modelling of seismic isolators;
- the seismic response of the structure for various configurations of seismic devices;
- determination of the nuclear island displacements, accelerations, floor spectrum;
- determination of the isolators displacements, shear and axial forces;
- assessment of the island response and the bearing capacity with the minimum and maximal isolator stiffness;
- study the floor spectrum for different points of interest of the isolated island response;
- verification of the design criteria for the isolators specified by the codes.
Risk assessment methodology of decay heat removal function against external hazards (such as Snow, Tornado, Wind, Rain, Forest fire, Volcanic ash, and combination hazards)

Objective

Development of the PRA methodology against volcanic eruptions

Volcanic ash hazards evaluation

Daisen-Tephra2 simulation
Stabilized Sodium boiling

Sodium boiling phenomena has been investigated with the CATHARE 2 thermal-hydraulic system code during a postulated ULOF transient.

The study focuses on a stabilized boiling case, allowing to avoid a fast temperature excursion in the fuel channel above the Na boiling temperature.

- In stabilized regime, the inlet cooling flow rate can be sustained under natural circulation within the subassemblies even if they have reached the saturation temperature. The two-phase flow quality remains low (typically below 1%).
- In case of unstabilized boiling, a flow redistribution would lead to the downwards progression of the boiling front within the core: the subsequent rise of the quality would then induce fuel pins dry-out.
The SAS4A metal fuel models have been extended to describe the phenomena associated with the metal fuel transient up to and beyond cladding failure.

These models allow the tracking of the fuel composition changes and the analysis of the important phenomenological effects of these changes on the transient events.

These results illustrate the effect of the variable metal fuel composition on the accident sequence of events and the need for modelling accurately the metal fuel behaviour.

The current status of the SAS4A metal fuel model development, and preliminary results of whole core analyses for PGSFR postulated severe accidents are presented.

Development and validation has been undertaken for the following SAS4A models:
- SSCOMP-A: pre-transient metal fuel characterization
- DEFORM-5A: transient metal fuel pin mechanics
- PINACLE-M: pre-failure in-pin metal fuel relocation
- LEVITATE-M: post-failure metal fuel relocation
Background

• Gaps in knowledge concerning radionuclide release from failed metal fuel into sodium
  – Sufficient data to estimate release fractions?

• Lack of cohesive radionuclide transport modeling computational tool
  – Need a trial MST calculation

Objective

• Using current tools and knowledge, attempt a complete mechanistic source term analysis
• Identify and prioritize any gaps in computational capabilities or data
• Continued focus on metal fuel, pool-type SFRs

Completed in 2016: SFR-SO-ยูนิฟอร์ม

Deliverable for 2017
Thank you for your kind attention!