Hands-on OpenMC introduction II

Jiwon Choe

Tuesday, August 8, 2023
Joint ICTP-IAEA Workshop on ONCORE

CONTENTS

China Experimental Fast Reactor (CEFR)

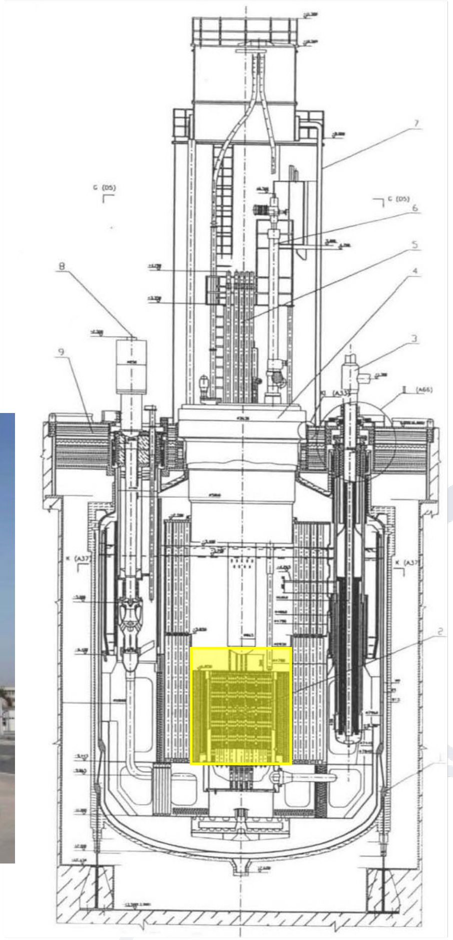
About CEFR

- **China's first fast neutron reactor**
- **Pool-type sodium-cooled oxide-fueled fast reactor with thermal capacity of 65 MW and 20 MWe**
- **Start-up tests in 2010-2011, operation in July 2011**

IAEA CRP (I31032) Neutronics Benchmark of CEFR Start-Up Tests

- **6 different start-up tests**
  - Fuel loading and criticality
  - Control rod worth
  - Sodium void reactivity
  - Temperature reactivity
  - Subassembly swap reactivity
  - Foil activation
- **Related TECDOC and TCS are publishing soon**

CEFR (Photo: China Institute of Atomic Energy)



1. Main Vessel
2. Reactor Core
3. Intermediate heat exchanger
4. Rotating plug
5. Control Rod Driving Mechanism
6. Fuelling Machine
7. Protective Cover
8. Main Pump
9. Fixed Shielding

Figure 1 CEFR Reactor Block

CEFR Core Specification

Main parameter of CEFR

Parameter	Value
Thermal/electric power, MW	65/20
Designed life, year	30
Maximum burn-up, MWd/t	60,000
Maximum neutron flux, $cm^{-2}s^{-1}$	3.2×10^{15}
Refueling period, day	80
Diameter/height of main vessel, m	8.0/12.2
Covering gas pressure, MPa	0.005
Core inlet/outlet temperature (full power), °C	360/530
SA lattice pitch, mm	61.0
SA outer/inner flat-to-flat dimension, mm	59.0/56.6
Wrapper thickness, mm	1.2

* All the parameters are given for first loading, at installation temperature of 20℃, and in nominal value or design value.

Key specifications

- Fuels
  - Fuel region of 450 mm with 64.4 wt.% ^{235}U of UO_2
  - Blanket region of 350 mm with 0.3 wt.% ^{235}U of UO_2
- B_4C with different ^{10}B enrichment
  - 2 regulating CRs (RE) with natural ^{10}B
  - 3 shim CRs (SH), 3 safety CRs (SA) with 92% enriched ^{10}B
  - Boron shielding subassemblies with natural ^{10}B

02 CEFR Core Specification & Configuration

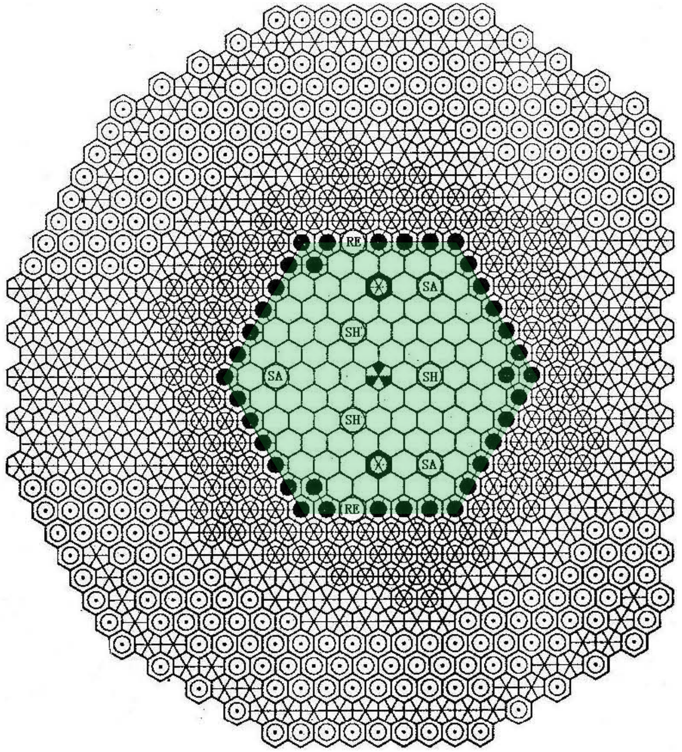
CEFR Core Configuration

CEFR Core Loading Layouts

Criticality with 72 fuel SAs & RE2 70 mm

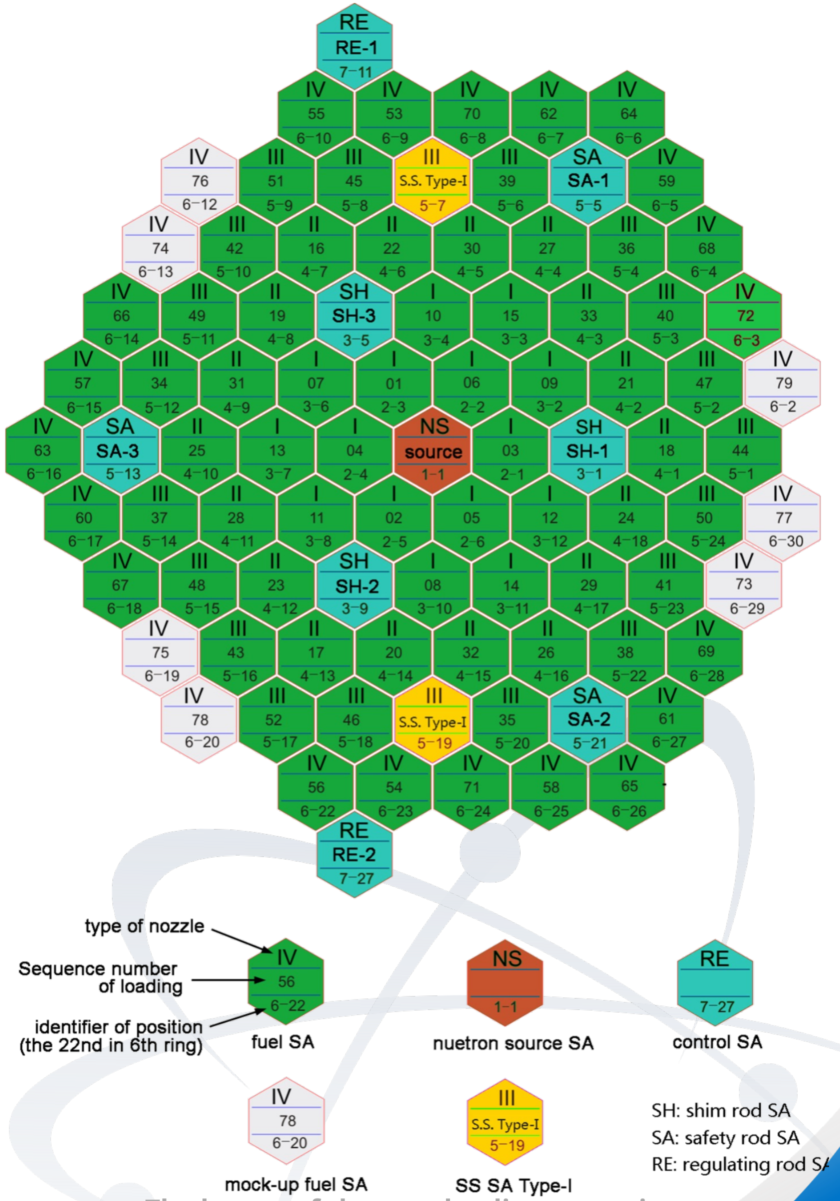
- Other CRs are at out-of-core

Operating core consists of 79 fuel SA



Legend	Assembly Type	Number
	Fuel Assembly	*79*
	1-Steel Shielding Assembly	*2*
	2-Steel Shielding Assembly	*37*
	3-Steel Shielding Assembly	*132*
	4-Steel Shielding Assembly	*223*
	Boron Shielding Assembly	*230*
SA	*Safety Rod Assembly*	*3*
RE	*Regulating Rod Assembly*	*2*
SH	*Shim Rod Assembly*	*3*
	Neutron Source Assembly	*1*

CEFR Core Layout (First Loading)



The layout of the core loading operation

What participants will do in this workshop

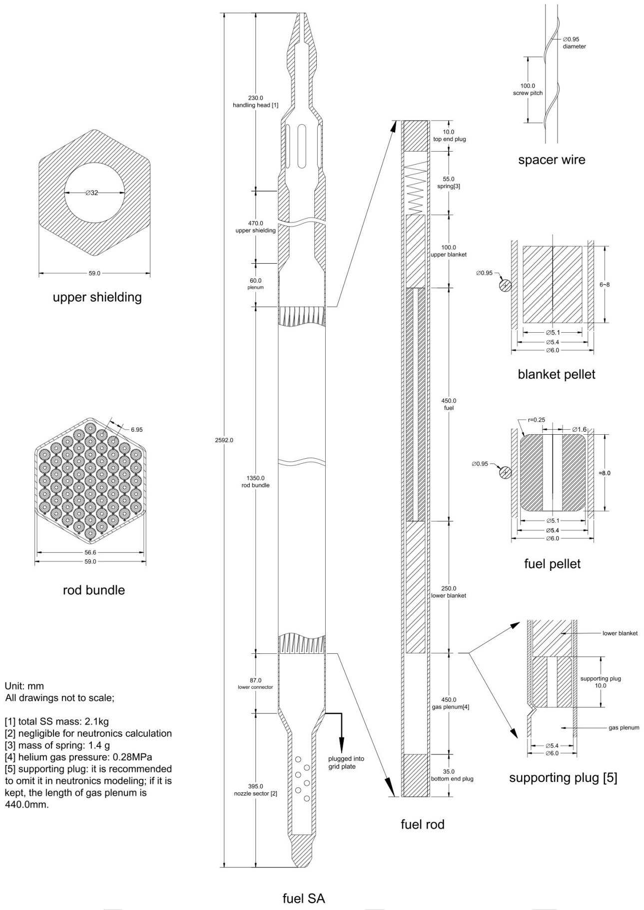
Single fuel sub-assembly modelling

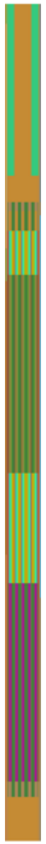
Preprocessing data

- Geometry expansion and material density change from room temperature (20℃) to cold state (250℃) based on measured information

Making OpenMC input script

- Define surfaces that make up the fuel subassembly
- Define pins and lattices in 2D for fuel region
- Stack universes in 3D
- Configure a core
- Set calculation options: basic options, plotting, and tallies





Simulation OpenMC

All participants get the same k-eff results

Visualization the output, such as pin-power distribution, flux spectrum

Optional Activities

- **The rest of the SAs can be defined in a similar manner**

- **Expanding this tutorial to modelling a whole core of CEFR**
  - **to simulate 3 simplified benchmarks based on CEFR Start-up Test**
    - first criticality, control rod worth, and sodium void reactivity.
  - **The IAEA TCS includes not only rest of core specifications but also modelling dataset of two Monte Carlo codes (OpenMC and Serpent)**

- **Let’s compare your results with those in the TCS**

04 References

- Fundamentals of Neutron Simulation of a Fast Reactor Based on IAEA's Benchmark of China Experimental Fast Reactor Start-up Tests, IAEA Training Course Series, IAEA-TCS-xx, Publishing soon

- Neutronics Benchmark of CEFR Start-Up Tests, IAEA TECDOC Series, IAEA-TECDOC-xxxx, Publishing soon (I31032)

- X. Huo, et al., Technical Specifications for Neutronics Benchmark of CEFR Start-up Tests (CRP-I31032), China Institute of Atomic Energy, 2019

- https://www.iaea.org/newscenter/news/new-crp-neutronics-benchmark-of-cefr-start-up-tests-i31032

THANK YOU