China Academy of Engineering Physics

Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization

Fuel management strategy of the pool type research reactor

2021.6

Institute of Nuclear Physics and Chemistry

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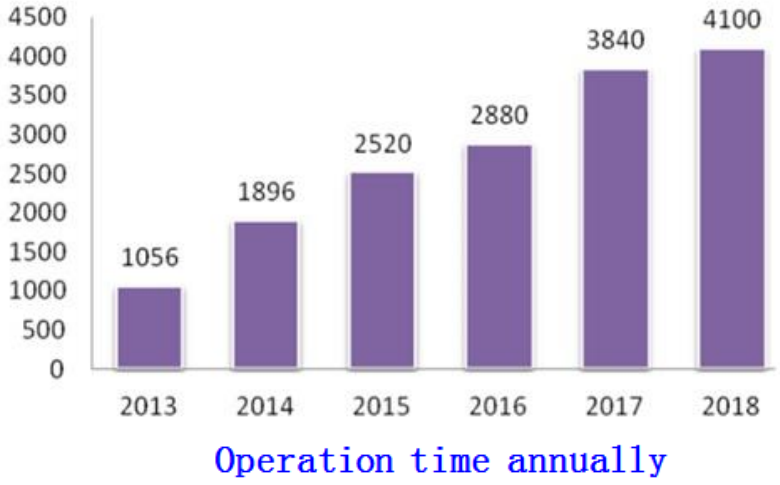
1. Brief introduction

About CMRR: CMRR is one of the three major neutron sources in China. They are China Mianyang Research Reactor (CMRR), China Advanced Research Reactor (CARR) and China Spallation Source (CSNS). Among them, the CMRR reactor has passed the acceptance check in 2012 and is currently operating normally in a stable state.

China Mianyang Research Reactor

- **Multifunctional pool type research reactor**

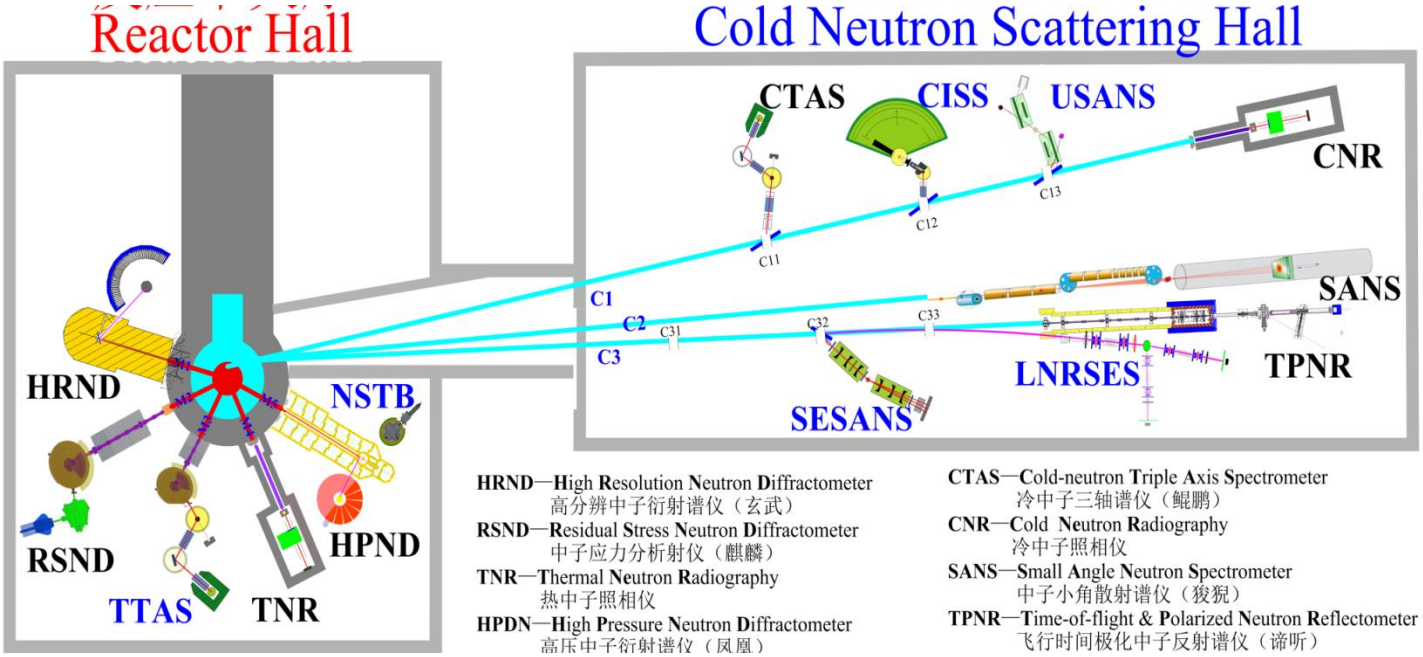
>200 days/2020



Neutron flux：

- Fast neutron： 3.7×10^{14} n/cm^2.s
- Thermal neutron： 2.4×10^{14} n/cm^2.s
- Cold neutron： 10^9 n/cm^2.s

CMRR Neutron Scattering Platform



HRND—High Resolution Neutron Diffractometer
高分辨中子衍射谱仪（玄武）
RSND—Residual Stress Neutron Diffractometer
中子应力分析射仪（麒麟）
TNR—Thermal Neutron Radiography
热中子照相仪
HPDN—High Pressure Neutron Diffractometer
高压中子衍射谱仪（凤凰）

CTAS—Cold-neutron Triple Axis Spectrometer
冷中子三轴谱仪（鲲鹏）
CNR—Cold Neutron Radiography
冷中子照相仪
SANS—Small Angle Neutron Spectrometer
中子小角散射谱仪（狻猊）
TPNR—Time-of-flight & Polarized Neutron Reflectometer
飞行时间极化中子反射谱仪（谛听）

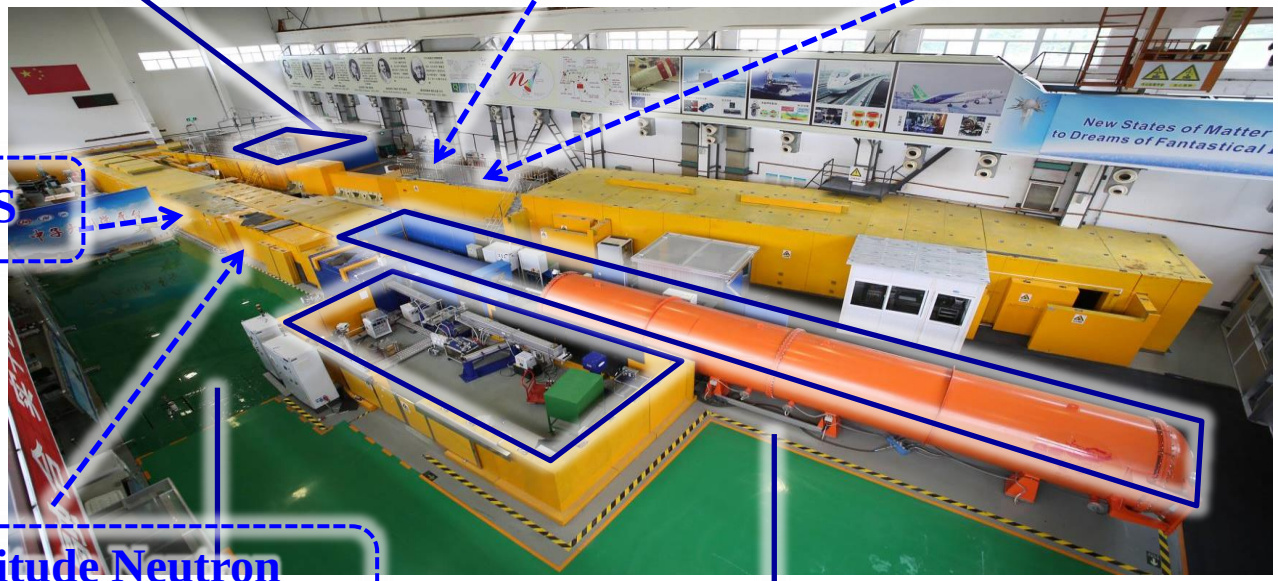
8 instruments are operational

Neutron Scattering Instrument layout

CTAS (Cold neutron Triple-Axis Spectrometer)

CISS (Cold-neutron Inelastic Scattering Spectrometer)

Ultra SANS



Spin Echo SANS

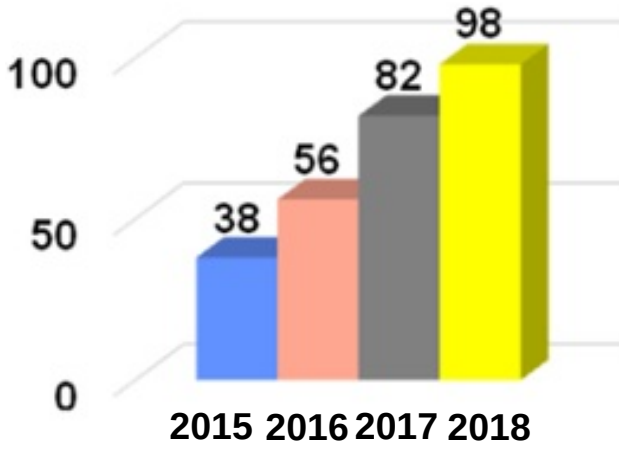
LNRSES (Latitude Neutron Resonance Spin Echo Spectrometer)

TPNR (Time-of-flight and Polarized Neutron Reflectometer)

SANS (Small-Angle Neutron Spectrometer)

CMRR—Users and Papers

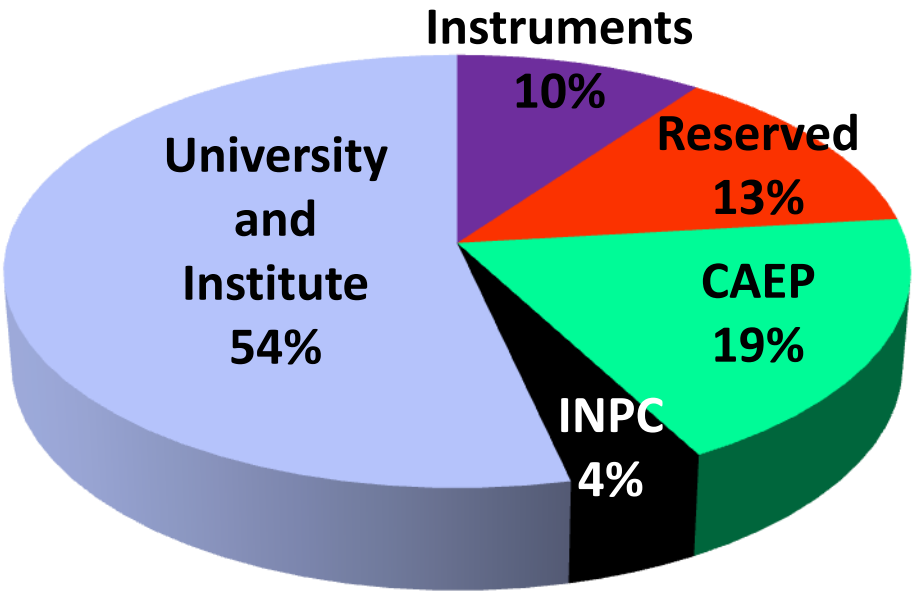
- **The users and papers are both increasing every year**
- **CMRR are playing a more important role in basic science and multi-field application**



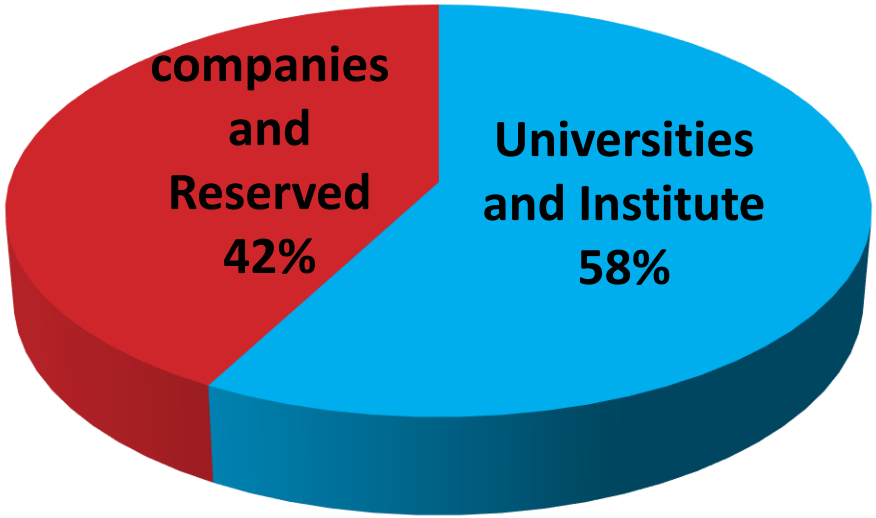
Number of users

Publication of papers

CMRR- Neutron beam distribution in 2018



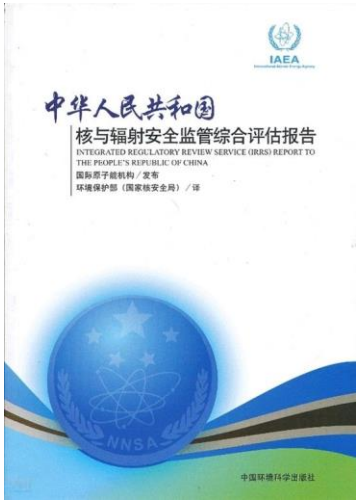
HRND



RSND

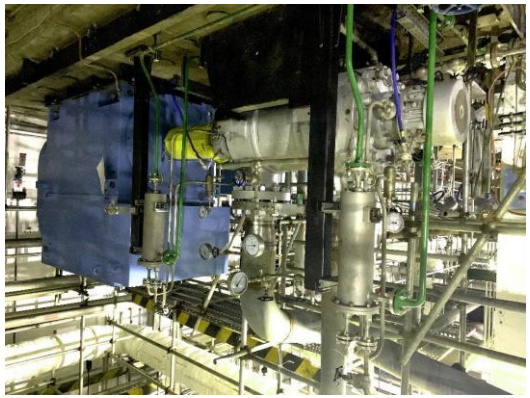
2. The Practice of the Code of Conduct on the Safety of Research Reactors

- aging management
- Research reactor life extension



About aging management:

- CMRR is a relatively young research reactor, but has done a lot of work in this area, including:
  - DCS system upgrade
  - secondary loop system upgrade
  - maintenance and dynamic tracking of spare parts library
  - ...



About Research reactor life extension:

- The Chinese Institute of Atomic Energy(CIAE), Nuclear Power Institute of China(NPIC), and Tsinghua University have made very active and useful explorations in these areas, and have achieved good results and performance.

- For a research reactor such as CMRR that has recently served, this matter has not yet been put on the agenda.

3. Fuel management strategy

3 aspects of the fuel management strategy

- Fuel loading/ refueling pattern
- Spent fuel burnup confirmation
- Spent fuel long-term storage

Fuel management computation toolbox system
Typical reactor physics measurements
Spent fuel confirmation

Contents lists available at ScienceDirect

Annals of Nuclear Energy

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Fuel management code system against experimental measurements of the CMRR reactor

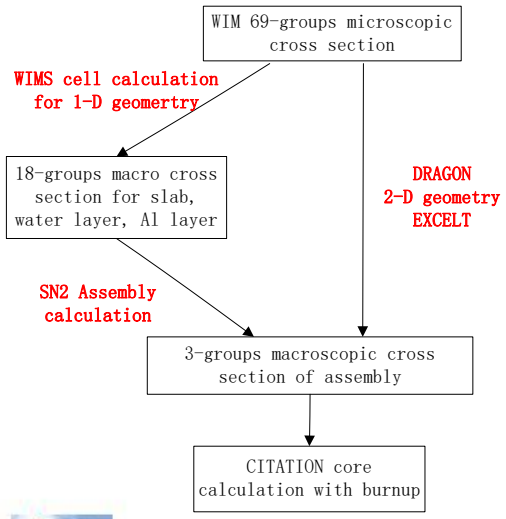
Guanbo Wang*, Dazhi Qian*, Jimin Ma, Rundong Li, Shu Yuan, Jun Leng, Haifeng Dou, Bin Tang

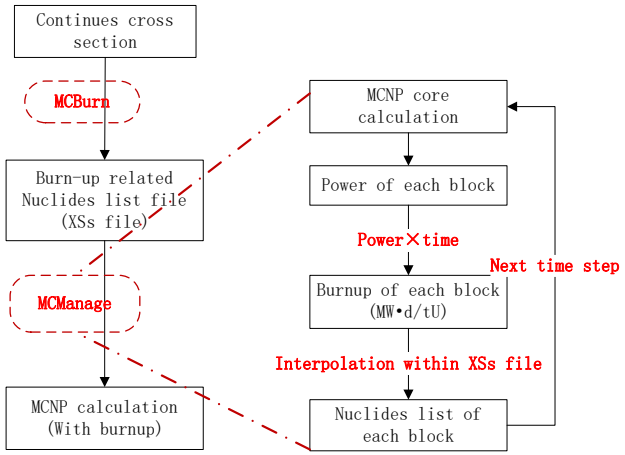
Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics (INPC), Mianyang 621900, China

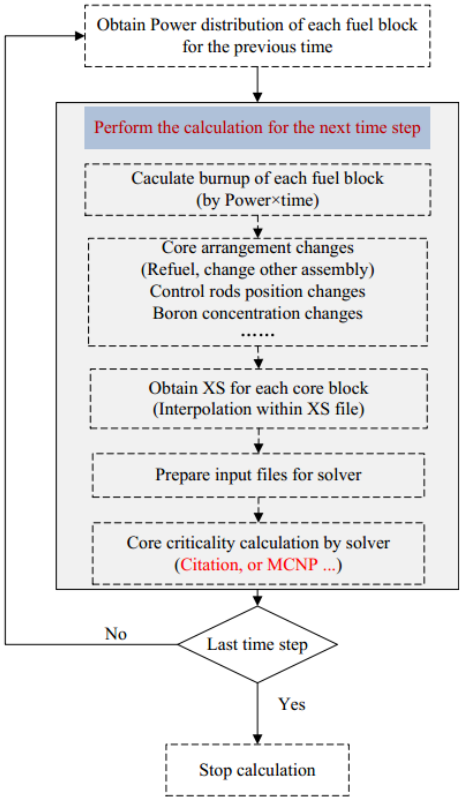
computation toolbox system

Mission and strategy:

- Creating refueling scheme, tracking the fuel history, calculating the fuel burn-up, and analyzing the nuclide stock of spent fuel elements.
- Improvement of simulation accuracy.
- Evaluate the sample's depletion





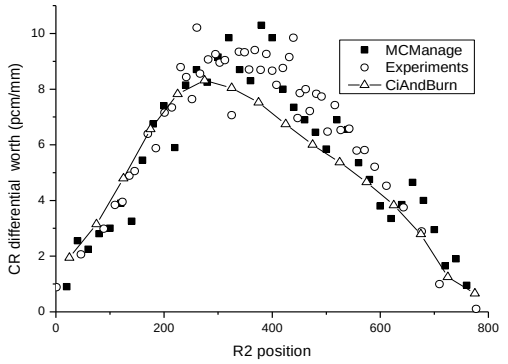


Typical reactor physics measurements

- including the control rods (CRs) critical position
  - An important global parameter to characterize the reactivity introduced by new assemblies
  - both the deterministic and MC ways, can get good prediction
  - the calculation accuracy is good enough for a flexible core loading and complex operation history research reactor

	(C-E) $\Delta k \times 100\%$	
	CiAndBurn	MCManage
1st before	-0.16	-0.551
1st after	-0.13	-0.550
2nd before	-0.10	0.108
2nd after	0	0.080
3rd before	0.32	-0.186
3rd after	-0.10	0.239
4th before	0.23	-0.222
4th after	0	0.170
5th before	0.48	-0.077
5th after	0.10	0.476

- the CR worth curve
  - Mandatory measurements according to the safety regulations
  - Self-developed reactivity meter, using the inverse kinetics method (IK) to measure CR differential worth.



- the thermal neutron flux distribution
  - Flux distribution & power peak factor
  - Dy-Al activation foils

Spent fuel burnup confirmation

- Compution
  - MCBurn
- Burnup measurements
  - A HPGe based measuring system was established
  - Three types of measuring method are studied(long-lived indicator (^{137}Cs) measuring method, the middle-lived indicator (^{95}Zr) based re-irradiation way, and the short-lived indicator (^{88}Kr, ^{91}Sr, ^{92}Sr, ^{135}I and ^{142}La) based re-irradiation way)
  - Experiments were performed.
- Storage
  - Spend fuel pool
  - Prevent CORROSION

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One candidate method based on short-lived indicator for burnup analysis

Shangquan Zhao[a,b], Guanbo Wang[b], Jimin Ma[b], Haifeng Dou[b], Rundong Li[b], Lei Zhang[b], Dazhi Qian[b,*]

[a] College of Energy, Xiamen University, Xiamen 361102, China
[b] Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics, Mianyang 621900, China

Thank you very much for your attention!