P-15

Layout of neutron beam instruments and irradiation devices for the new research reactor planned to be installed at the Monju site

Synergy Sustainable Ubiquitous

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1. Introduction

The new research reactor (hereinafter as "New Research Reactor"), which is planned to be installed at the Monju site in Fukui prefecture, is a light water moderated and cooled pool type reactor with heavy water reflector whose main purpose is to utilize neutron beams, and its thermal power is less than10MW. In order to achieve maximum performance under these conditions, the New Research Reactor needs to be designed taking into consideration various factors from various perspectives, such as a compact core design and a high-performance cold neutron source (CNS). In addition, to maximize the number of neutron beam instruments and irradiation devices to be installed in this New Research Reactor and to maximize their performance, various factors including requests from the users of those instruments/devices are being considered and a layout plan focusing mainly on the reactor room is being prepared. This is to report the current proposal for the layout of the utilization instruments and equipment for the New Research Reactor.

2. Instruments and equipment planned to be installed in the New Research Reactor and the requirements from them

Tables 2.1 and 2.2 show the instruments and equipment that are desired to be installed in the reactor room and guide hall of the New Research Reactor. Table 2.3 shows the dates of the meetings with the task force members. When considering the layout of the experimental equipment, discussions were held with user groups (called "task force") for each experimental topic.

Table 2.1 Priority 5 instruments/devices in the New Research Reactor (instruments to be installed with priority)

Methods	Instruments & Equipment	Place of install
Beam	Small Angle Neutron Scattering	Guide Hall
Beam	Neutron Imaging Facility	Reactor Room, Guide Hall
Beam	Neutron Powder Diffractometer	Reactor Room, Guide Hall
Beam	Neutron Reflectometer	Guide Hall
Irradiation	Neutron Activation Analysis	Reactor Room, Hot Laboratory

Table 2.2 Instruments and devices to be installed in the Reactor Room of the New Research Reactor (other than priority 5 equipment)

Methods	instruments & Equipment	Place of install
Beam	Cold Neutron Triple-Axis Spectrometer	Reactor Room
Beam	Ultra cold neutron beam facility	Reactor Room
Beam	Biological irradiation	Reactor Room
Irradiation	Slow Positron Beam system	Reactor Room
Irradiation	Material irradiation	Reactor Room
Irradiation	Research Radioisotope production	Reactor Room

Table2.3 Discussion with the Task Force

Task Force	Date of discussion
Slow Positron Beam system	Aug. 29th, 2024 & Aug. 26th, 2024
Biological irradiation	Jul. 16th, 2024
Ultra cold neutron beam facility	Jul. 16th, 2024 & May 27th, 2025
Neutron Activation Analysis	Jul. 16th, 2024
Research Radioisotope production	Jul. 16th, 2024 & Jan. 21st, 2025
Material irradiation	Jul. 16th, 2024 & Aug. 30th, 2024
Cold Neutron Triple-Axis Spectrometer	Sep. 30th, 2024
Neutron Powder Diffractometer	Sep. 30th, 2024
Neutron Imaging Facility	Nov. 8th, 2024
Hot Laboratory Facility	Jan. 21st, 2025

Tables 2.4 and 2.5 show information based on requests from the task force regarding the layout of instruments and facilities desired to be installed in the new research reactor.
Regarding the layout of equipment for experiments, priority is currently given to the layout of equipment to be installed in the reactor room.

- Most of the neutron beam instruments are desired to be extracted tangential to the core to prevent contamination of gamma rays, so the horizontal beam tube are to be installed as such.
- Only the Ultra Cold Neutron facility does not have a tangential extraction to prevent contamination of gamma rays.
- Since the positron source requires a very large-diameter irradiation hole for the positron production, we decided to prepare a ϕ180 mm irradiation hole.
- Large-diameter (ϕ100 mm) irradiation holes were prepared for irradiating materials.

Table 2.4 Instruments and equipment proposed to be installed in the reactor room of the New Research Reactor (using horizontal beam tubes)

Instruments and equipment	Size and direction of beam duct	Exclusive area	Flux
Thermal neutron guide tube	ϕ200mm, tangential direction		
Cold neutron guide tube	ϕ200mm, tangential direction		
Neutron Imaging Facility	ϕ200mm, tangential direction	8m x 13m	10^8 n/cm2/s at downstream stage 10^9 n/cm2/s at upstream stage
Neutron Powder Diffractometer	ϕ80mm tangential direction	6.5m x 7.5m	
Cold Neutron Triple-Axis Spectrometer	ϕ150～180mm tangential direction	4.5m x 6m～7.1m x 5.8m	10^12 n/cm²/s at the monochromator position.
Ultra cold neutron beam facility	ϕ200mm, do not need tangential direction	10m×10m	10^9 n/s(Cold neutron)
Biological irradiation	ϕ300mm, tangential direction	4m(width)×4m(depth)×2m(height)	5 x 10^9～1 x 10^10 n/cm²/s

Table 2.5 Instruments and equipment proposed to be installed in the reactor room of the New Research Reactor (using vertical experiment holes)

Instruments and Equipment	Size and number of vertical experiment holes	Exclusive area	Fluxes, etc.
Neutron Activation Analysis	ϕ50mm x 5 vertical experiment holes (Hydraulic irradiation facility) ϕ50mm x 6 vertical experiment holes (Pneumatic irradiation facility) ϕ100mm x 1 vertical experiment holes (Slant irradiation facility)	Hot Laboratory	Same level as JRR-3 facilities
Slow Positron Beam system	ϕ180mm x 1 vertical experiment holes	25m×20m (Experimental area using slow positron beam)	
Material irradiation	ϕ100mm x 2 vertical experiment holes ϕ65mm x 2 vertical experiment holes	2m x 2m for measuring instruments	Use fast neutrons (less thermal neutrons are better)
Medical Radioisotope Production	ϕ50mm x 3 vertical experiment holes ϕ65mm x 2 vertical experiment holes		Therapeutic radioisotopes production 1 x 10^14 n/cm²/s or more

3. Layout of instruments and devices in the reactor room (Draft)

Based on the request from the task force, several layouts of instruments and equipment for experiments around the reactor core were proposed. One of the proposed layouts of instruments and equipment is shown in Figures 3.2 and 3.3.
Figure 3.2 shows the layout of the building, instruments and equipment for the experiments. Figure 3.3 shows the arrangement of the horizontal beam tubes and vertical experiment holes around the reactor core. The layout of instruments and equipment reflects the requests from the task force as much as possible.

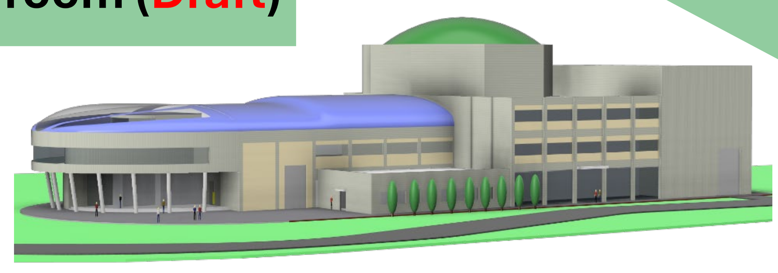


Figure 3.1 Image of the reactor facility

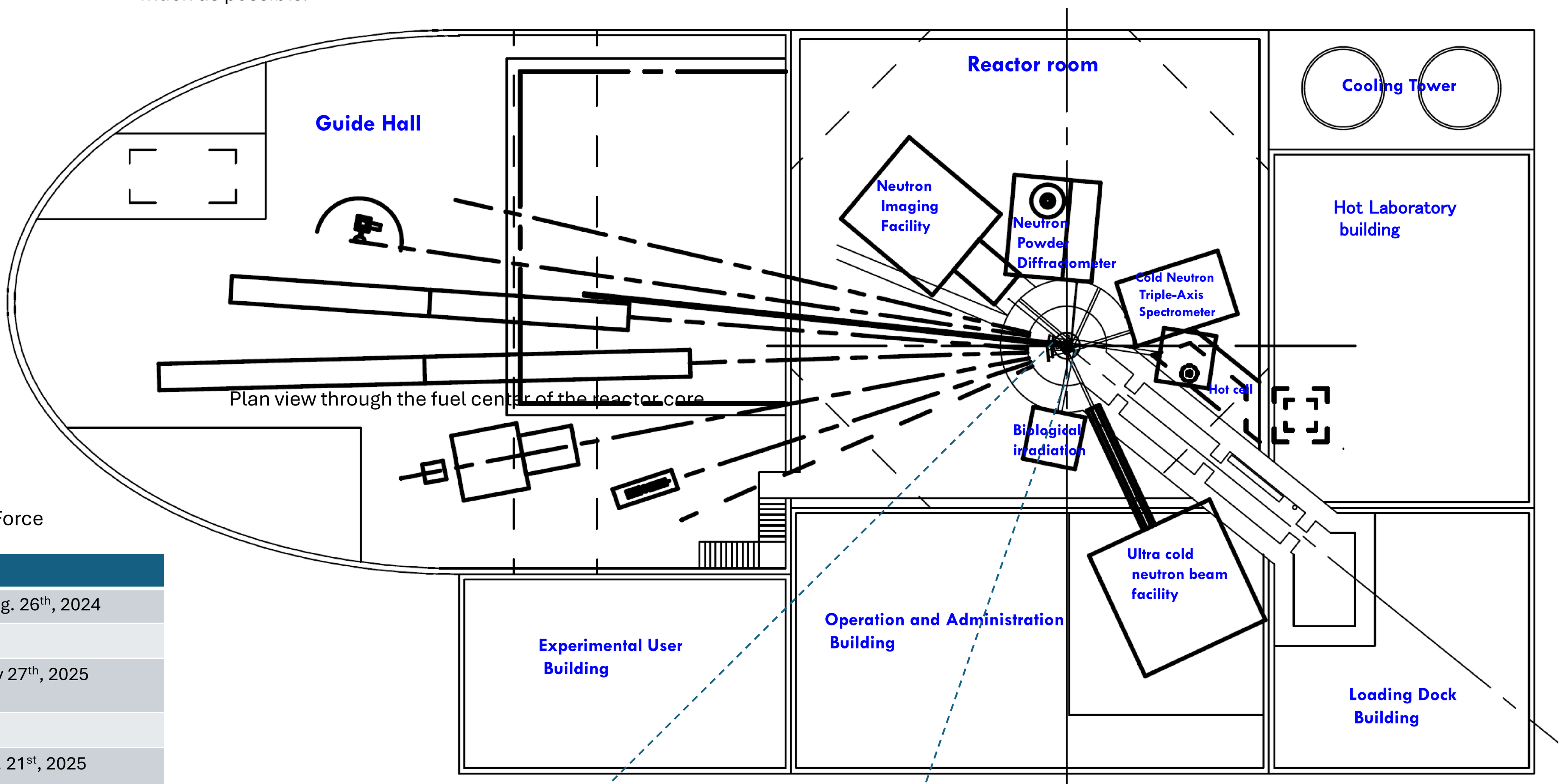
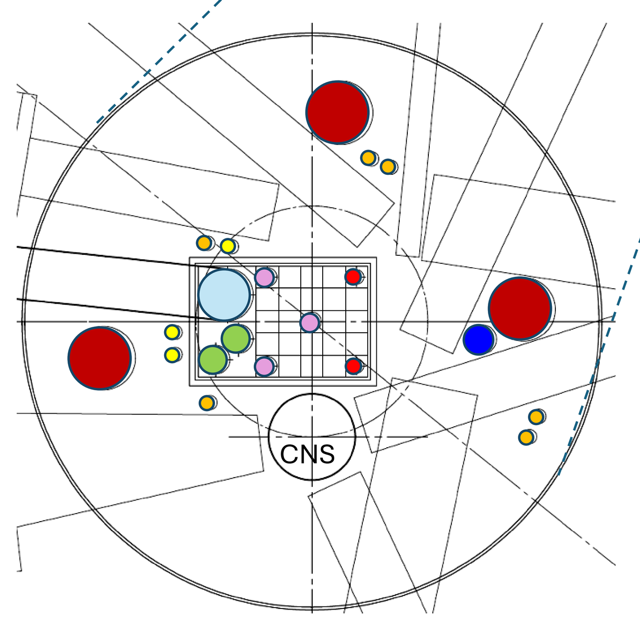


Figure 3.2 Layout of New Research Reactor building, instruments and equipment (Draft 1)



- : Vertical experiment hole（ϕ65mm）x 3 (holes in the core)
- : Large Diameter experiment hole x 1（ϕ180mm hole for Slow Positron Beam system）
- : Large Diameter experiment hole x 2（ϕ100mm hole for Material irradiation）
- : Hydraulic irradiation facility x 3（ϕ50mm Vertical experiment holes）
- : Mechanical Irradiation facility x 2（ϕ50mm Vertical hole in the core） (Instead of Hydraulic irradiation facility)
- : Pneumatic irradiation facility x 6（ϕ50mm holes） Near (2 holes), in the middle (2 holes), and far (2 holes) from the reactor core
- : Slant experiment Hole 1（ϕ100mm）
- : General-purpose experiment hole x 3（ϕ220mm）
- : Location of CNS (Cold Neutron Source)

Figure 3.3 Layout around the reactor core (Draft 1)

4. Evaluation of the neutron beam distribution obtained from the proposed arrangement of the instruments and equipment

Calculations were performed to evaluate the effect of the horizontal beam tube in the heavy water reflector region on the thermal neutron beam distribution when criticality is reached.

1. The thermal neutron flux distributions with the following three models based on a typical planned C20 core were calculated.
   a. No experiment hole (model name: "a. C20")
   b. With large vertical experiment holes (model name: "b. C20A without horizontal beam tubes")
   c. All experiment holes (model name: "c. C20A with horizontal beam tubes")
2. The calculation conditions are as follows.
   a. Vertical experiment holes in the core are filled with water.
   b. Vertical experiment holes for material irradiation located at the side are filled with water.
   c. Vertical experiment hole for positron source installed is void.
   d. Vertical experiment holes for cold neutron source installed is void.
   e. The horizontal beam tube is a void.
   f. The codes and libraries used in the calculations are MCNP6.2 and AceLibJ40 (JENDL4.0).
   g. The criticality(K-eff) and the control rod positions in the calculations are shown in Table 4.1.
3. When the horizontal beam tubes and some vertical experiment holes are placed, the thermal neutron flux intensity at the plane where the horizontal beam tubes are placed (z=0 cm) is decreased.

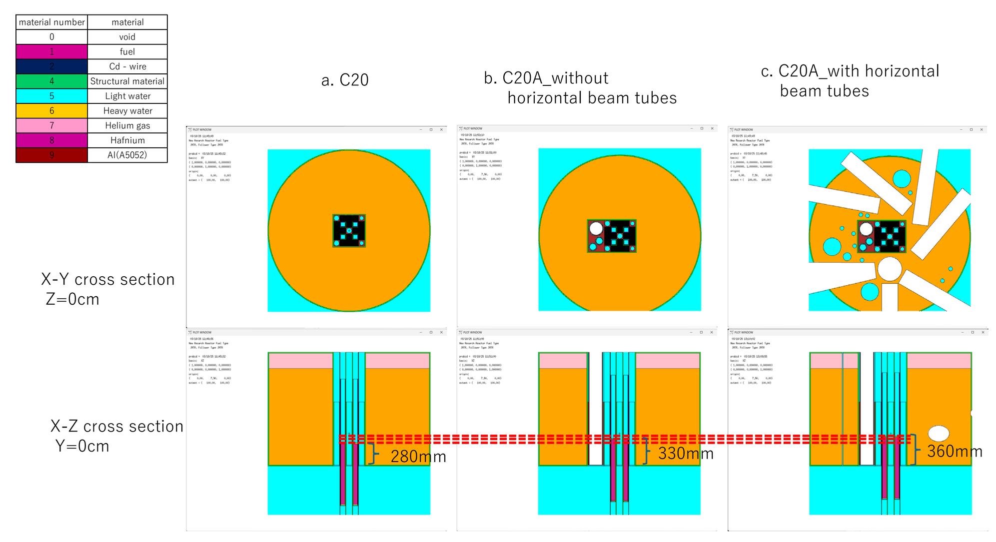
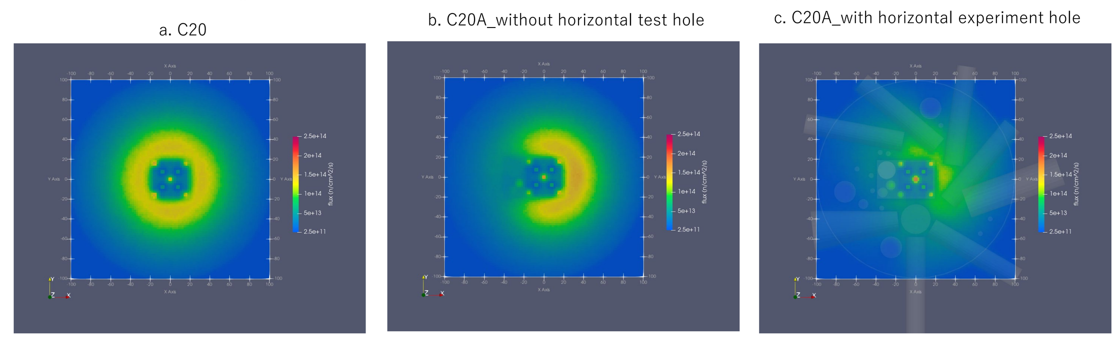


Figure 4.1 Calculation models for thermal neutron flux distribution

Table 4.1 Calculated criticality(K-eff) and control rod positions

model	K-eff	Control rod B2	Control rod B4	Control rod D2	Control rod D4
a. C20	1.00391 (0.00025)	280mm	280mm	280mm	280mm
b. C20A Without horizontal beam tubes	1.00775 (0.00026)	330mm	330mm	330mm	330mm
c. C20A With horizontal beam tubes	1.00022 (0.00027)	360mm	360mm	360mm	360mm

Thermal group neutron flux distribution (<5E-7 MeV at criticality adjustment)



X-Y cross section Z=0cm (center of effective length of fuel, height of center of horizontal experiment hole)
The scale of the color distribution was adjusted. The color distribution is shown as linear.

Figure 4.2 Calculation results of thermal neutron flux distribution

5. Current Status and Future Plan

We are still collecting user requirements for the utilization of instruments and equipment, and we will incorporate them into the layout design of the New Research Reactor.
We will also evaluate the neutronic characteristics in the new layout, such as neutron flux distribution, and confirm the performance of the instruments and equipment.
We are working to establish and validate appropriate evaluation methods.

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