Decommissioning Plan of JRR-4

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ABSTRACT

Japan Research Reactor No.4 (JRR-4) is a swimming pool type reactor moderated and cooled with light-water. The maximum thermal power of JRR-4 is 3,500kW. Since its initial criticality in January 1965, JRR-4 had been operated about 45 years until in December 2010.

Subsequently, the Great East Japan Earthquake occurred on March 11, 2011. Although JRR-4 was no severe damage, we have determined to decommission JRR-4 in consideration of various things. After that, we have submitted the decommissioning plan of JRR-4 to the nuclear regulatory body and have received the approval of it on June 7, 2017. Consequently, JRR-4 has shifted to the phase1 of the decommissioning plan since December.15, 2017 after the approval of its the safety regulation.

Keywords: JRR-4, decommissioning plan, evaluation of radioactivity, evaluation of total amount of waste, decommissioning program, permanent shutdown, export of fuel, cooling management, dismantlement

1. INTRODUCTION

JRR-4 is a swimming pool type reactor moderated and cooled with light-water. The maximum thermal neutron flux is 7.0×10^{17} n/m^2・sec. General view of JRR-4 is shown in Fig.1, cutaway view of the core tank is shown in Fig.2.

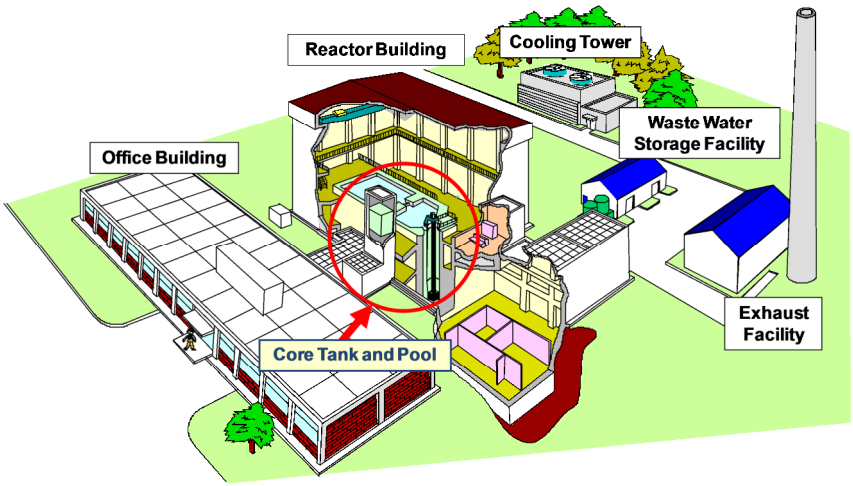

Fig 1. General view of JRR-4

The core tank surrounds the reactor core for flow of coolant. The core tank is cylindrical type with 1.5 m in diameter, and 11 m in height. It's made of corrosion resisting aluminum alloy.

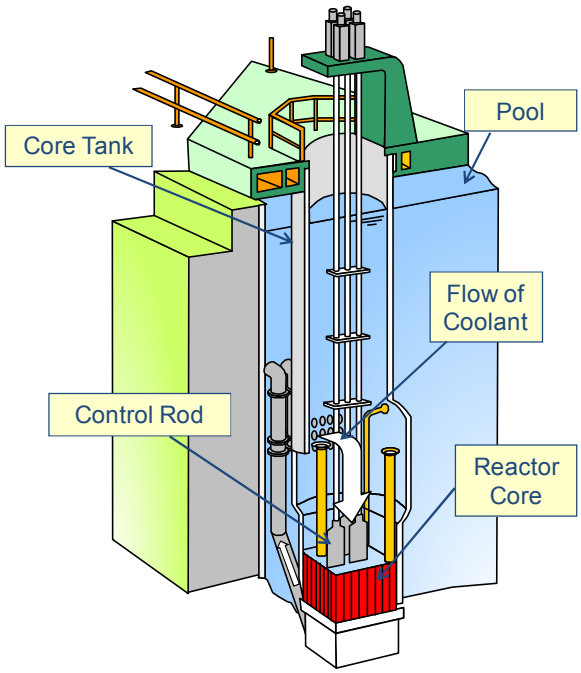

Fig 2. Cutaway view of the core tank of JRR-4

Layout of the reactor core is shown in Fig.3. The reactor core is located in the bottom of the core tank, and composed of 20 fuel elements, 32 graphite reflectors and 3 aluminum reflectors, 5 control rods & 2 backup rods, 5 irradiation pipes and a Am-Be neutron source. The size of the reactor core is 67 cm in length,65cm in width, and 60 cm in height.

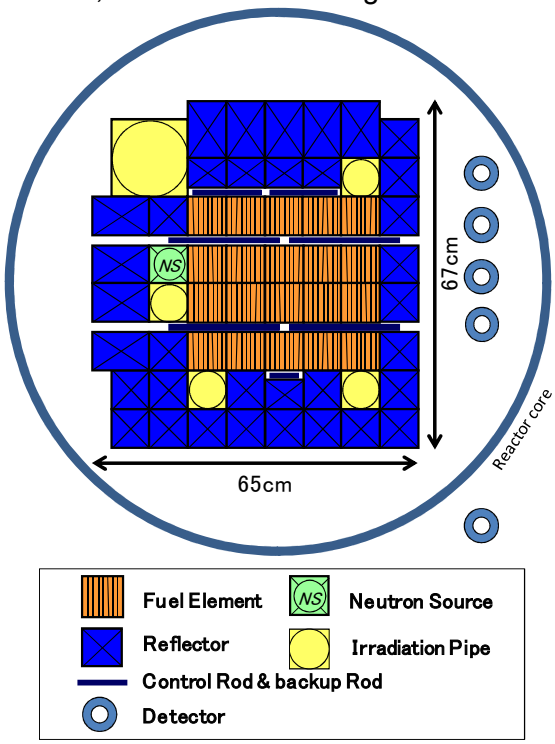

Fig 3. Layout of the reactor core of JRR-4

Cooling system of JRR-4 is shown in Fig.4. It has 3 main pumps, 1 sub Pump and 4 strainers for primary cooling, 2 pumps for secondary cooling, 2 purification

system, and 2 heat exchangers.

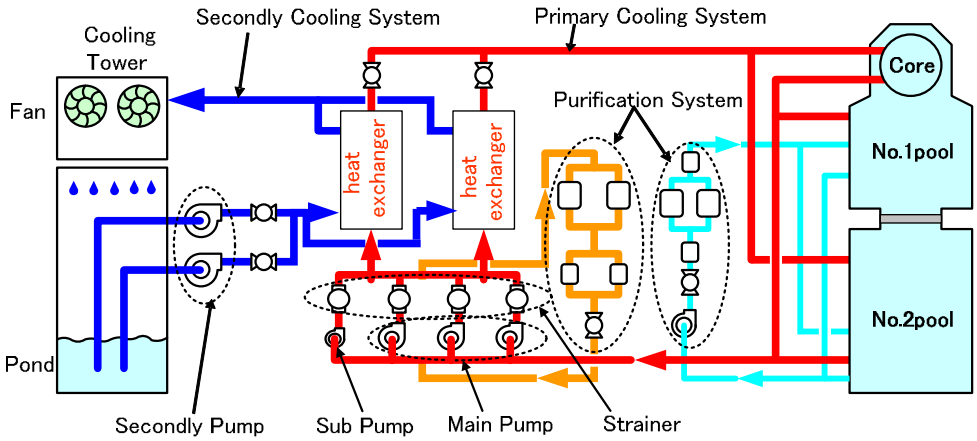

Fig 4. Cooling system of JRR-4

History of JRR-4 is shown in Tab 1. Since its initial criticality in January 1965, JRR-4 had been widely utilized such as shielding experiment, experiment of fuel,material irradiation, radioisotope production, neutron transmutation doping for silicon semiconductor, neutron activation analysis (NAA) and training of reactor operation for nuclear engineers until in January 1996. After terminated HEU(93% enriched uranium) operation in January 12, 1996, JRR-4 modification was planned for its core conversion according to the Reduced Enrichment for Research and Test Reactors(RERTR) program, utilization facilities upgrading ,and so on. The fuel element was changed from HEU to LEU (Approximate 20 % uranium silicide fuel). Some utilization facilities such as a medical irradiation facility for BNCT (Boron Neutron Capture Therapy) and so on were also modified.

Subsequently, since its initial criticality with LEU fuels in July 14, 1998, JRR-4 had been widely utilized until in December 2010.

JRR-4 has suffered the great earth tremor not previously experienced when the Great East Japan Earthquake occurred on March 11, 2011. At that time, JRR-4 was undergoing regular periodical inspection and the reactor was not operated. Although commercial electric supply was stopped, necessary minimum facilities were continuously operated with emergency electric generators. It is very important to confirm immediately whether nuclear fuel materials and reactor containment systems are damaged or not. During the aftershocks for a few hours, the pool, nuclear fuels and their storage facilities were checked visually and confirmed to keep their soundness. Although several small cracks were shown on the inside of the walls of the reactor building, they did not result in adverse effect on the integrity of containment and there was no release of radioactive materials to environment.

Nuclear facilities in JAEA were planned to be decommissioned considering their importance, ageing condition, necessary expense and so on. In September 2013, we have determined to decommission JRR-4.

Date	Item
June 1962	Beginning of JRR-4 construction
January 28,1965	Initial criticality with HEU fuels
November 1965	Beginning of 1000kW operation
November 1965	Shielding experiment
March 1966	Power up to 2500kW
June 1969	Beginning of Joint utilization operation
October 1976	Power up to 3500kW
January 12,1996	Terminated the reactor operation with HEU fuels ・total output power: 58,666Mwh ・total operation times: 29,379 hours
January 1996	Beginning of modification works
July 14, 1998	Criticality with LEU fuels
December 24, 2010	Terminated the reactor operation with LEU fuels ・total output power: 20,868Mwh ・total operation times: 9,441 hours
March 11,2011	The Great East Japan Earthquake
September 2013	Determination of decommissioning of JRR-4

Tab 1: History of JRR-4

2. DECOMMISSIONING PLAN

It is necessary to get approval of decommissioning plan from the nuclear regulatory body for decommissioning research reactors in Japan. Decommissioning plan includes several contents such as target of decommissioning, evaluation of radioactivity, evaluation of total amount of waste, and decommissioning program, and so on. Therefore, we have submitted the decommissioning plan of JRR-4 including them to the nuclear regulatory body, and have received the approval of it on June 7, 2017.

2.1 Target of decommissioning

The target of decommissioning is all buildings except for the office building. The arrangement of buildings after decommissioning is shown in Fig.5.

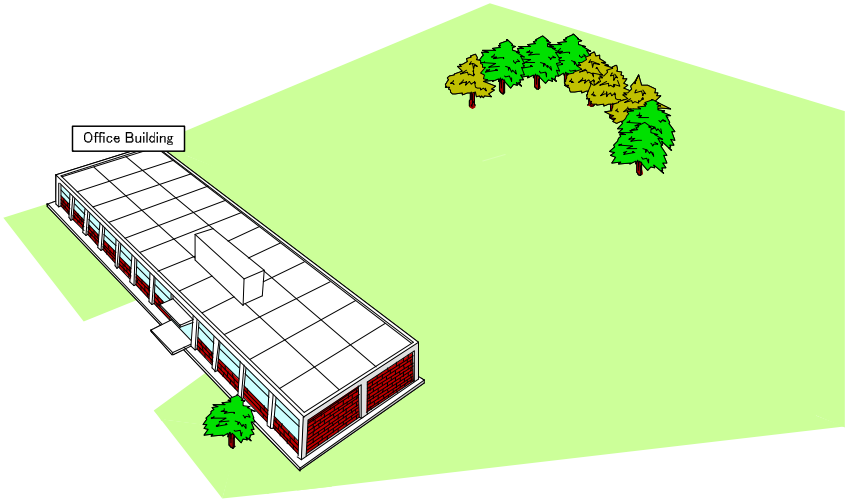

Fig 5. Arrangement of buildings after decommissioning

2.2 Evaluation of radioactivity

Radioactivity is categorized into activation radioactivity and contamination radioactivity.

The activation radioactivity exists near the reactor core, so the effective dose near the reactor core is very high. Moreover it is important to evaluate the activation radioactivity accurately for the purpose of the reduction of waste and costs. Therefore, the activation radioactivity was evaluated using MCNP5, COUPLE and ORIGEN-S.COUPLE and ORIGEN-S are included in Scale6.1.

On the other hands, the contamination radioactivity exists on the surface of the primary cooling system, the reactor core and the pool. The maximum contamination radioactivity exists in the area of strainers in the primary cooling system. Even this area the effective dose is very low. Therefore, the contamination radioactivity was evaluated using measured data in this area directly.

Total activation radioactivity is 2.5×10^{13} Bq in 2015. Main nuclides are H-3, Fe-55, and Co-60, they are 1.3×10^{13} Bq, 6.7×10^{12} Bq, and 3.5×10^{12} Bq respectively. Incidentally, Almost of H-3 is generated by Li-6 (n,α) H-3 reaction in LiF and aluminum.

Total contamination radioactivity is 6.4×10^{10} Bq in 2015, all nuclide is Co-60 except H-3 in heavy water.

Above all, total radioactivity which includes total activation radioactivity and total contamination radioactivity is 2.5×10^{13} Bq in 2015. And we find that JRR-4 is almost activation radioactivity, because activation radioactivity is approximately larger than three digits comparing with contamination radioactivity.

The change of the activation radioactivity of main structures is shown in Fig.6.

The Activation radioactivity of main structures decays especially for 10 years from just after shutdown (2010) to 2021. This is mainly caused by decay of short life nuclide.

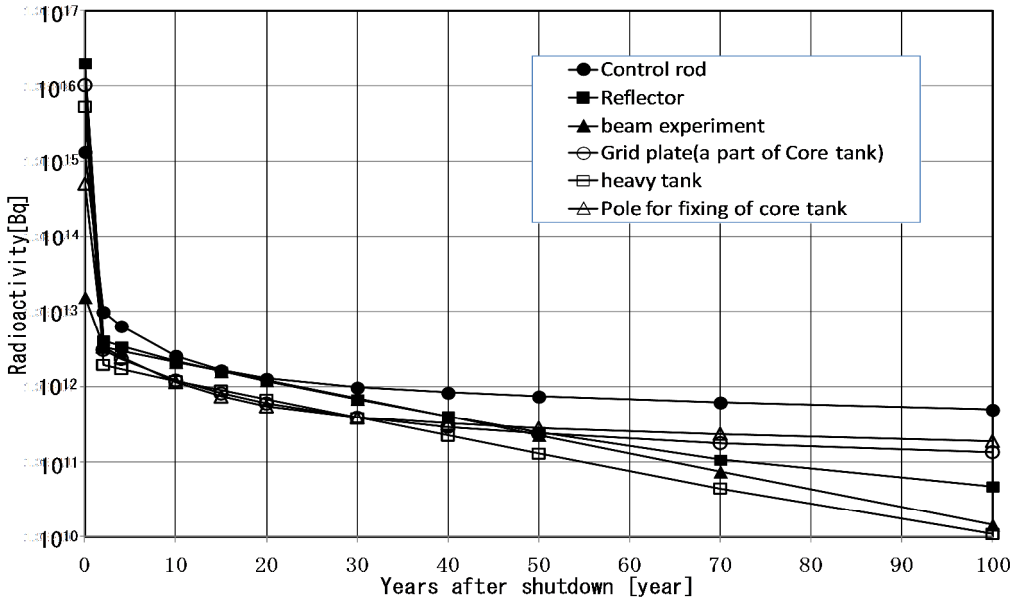

Fig.6. Change of activation radioactivity of main structures

2.3 Evaluation of total amount of waste

The total amount of waste was evaluated using the result of the evaluation of radioactivity. The waste consists of 5 kinds of wastes, they are reactively higher level radioactive waste (L1), reactively lower level radioactive waste (L2), very low level radioactive waste(L3), waste that need not to be treated as radioactive waste(clearance) and non-radioactive waste (NR), respectively.

The total amount of waste is 13,400* tons, almost of them is the concrete of clearance and NR in 2021.

The total amount of L1, L2 and L3 are 0.002 tons, 3 tons, and 782* tons, respectively in 2021.

2.4 Decommissioning program

After the approval of the decommissioning plan and its safety regulation, the decommissioning program of JRR-4 is planned for at least 16 years, and the decommissioning program of JRR-4 is divided into 3 phases. It is shown in Tab 2.

	A.D.		Necessary year
	2017-2021	2021-	12 years
Phase	Phase 1 (Permanent shutdown) (export of fuel)	Phase 2 (Cooling management)	Phase 3 (Dismantlement)

The approval of decommissioning plan and safety regulation

Decommissioning completion

Tab 2: Decommissioning program of JRR-4

* provisional value

Phase1: Permanent shutdown and export of fuel

JRR-4 has shifted to phase1 of the decommissioning plan since December.15, 2017.

In phase 1, we fix control rod that is inserted fully after removal of fuel from reactor core for permanent shutdown. It has finished. And we export fuel from JRR-4 to U.S.DOE.

Phase2: Cooling management

The phase 2 is cooling term for decay of radioactivity. We carry out cooling management until at least 2021, and the length of cooling term has been decided considering the results of evaluation of activity.

Phase3: Dismantlement

In phase 3, JRR-4 will be dismantled finally. We have not yet decided precise schedule of dismantlement, in addition, we do not know radioactivity accurately at dismantlement. Therefore, we decide detailed dismantlement method, procedure, and so on after we decide commencing time of dismantlement.

3. Conclusions

We have determined to decommission JRR-4 in 2013, consequently, we have received the approval of the decommissioning plan of JRR-4 to the nuclear regulatory body on June 7, 2017. Then, JRR-4 has shifted to phase1 of the decommissioning plan since December 15, 2017 after the approval of its safety regulation.

Decommissioning plan includes several contents such as target of decommissioning, evaluation of radioactivity, evaluation of total amount of waste, and decommissioning program, and so on.

Target of decommissioning is all buildings except for the office building.

Total radioactivity is 2.5×10^{13} Bq in 2015, main nuclides are H-3, Fe-55, andCo-60.

Total amount of waste is 13,400 tons at 2021, almost of them are the concrete of clearance and NR.

The decommissioning program of JRR-4 is planned for at least 16 years, and divided into 3 phases. Phase1 is permanent shutdown and export of fuel, phase2 is cooling management until at least 2021, phase3 is dismantlement. We will decide detailed dismantlement method, procedure, and so on after we decide commencing time of dismantlement.

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