INTERNATIONAL NUCLEAR SAFETY JOURNAL
vol.3 issue 4, 2014, pp.16-24

ISSN 2285 – 8717
ISSN–L 2248 – 8717
http://www.insj.info

Experiences on Research Reactors Decommissioning in the NSRI of the JAEA

Mitsuo Tachibana, Katsumi Kishimoto, Kunio Shiraishi
Japan Atomic Energy Agency, Japan
Corresponding author: *tachibana.mitsuo@jaea.go.jp*

Received: *5 November 2014*; accepted: *19 November 2014*

Abstract
Three research reactors were permanently shut down in the Nuclear Science Research Institute (NSRI) of the Japan Atomic Energy Agency (JAEA) as of October 2014. Safe storage or one-piece removal method was applied to decommissioning of these research reactors depending on decommissioning cost and utilization of facilities and so on. Various kinds of data and experiences were obtained through decommissioning of these research reactors. This report shows data and experiences on the research reactors decommissioning in the NSRI of the JAEA.

Keywords
decommissioning, JRR-1, JRR-2, JRR-3, one-piece removal, safe storage

1. Introduction

After establishment of the Japan Atomic Energy Research Institute (JAERI, former body of the Japan Atomic Energy Agency (JAEA)) in June 1956, 5 research reactors were constructed in the Nuclear Science Research Institute (NSRI) in JAEA: the Japan Research Reactor No.1 (JRR-1), the Japan Research Reactor No.2 (JRR-2), the Japan Research Reactor No.3 (JRR-3), the Japan Research Reactor No.4 (JRR-4), the Nuclear Safety Research Reactor (NSRR). Table 1 shows outline of research reactors in the NSRI of the JAEA.

The three research reactors (the JRR-1, the JRR-2 and the JRR-3) of them were permanently shut down in the NSRI of the JAEA as of October 2014 after finishing their roles. Safe storage or one-piece removal method was applied to decommissioning method of these research reactors depending on decommissioning cost and utilization of facilities and so on.

Various kinds of data such as manpower and radiation exposure and experiences were obtained through decommissioning of these research reactors.

The JRR-3M reactor body was constructed in the original location in the reactor building after removal of the JRR-3 reactor body. The first criticality of the JRR-3M was achieved in March 1990 and its utilization was started in November, 1990.

The JRR-3M, the JRR-4 and the NSRR has waited for restarting reactor after permission of new regulatory requirement for research reactors, and nuclear waste storage/ disposal made by the Nuclear Regulation Authority of Japan (NRA) in 2013.

This report shows outline of decommissioning, data and experiences on decommissioning of the JRR-1, the JRR-2 and the JRR-3 in the NSRI of the JAEA.

2. The JRR-1 Decommissioning [1, 2]

The JRR-1 attained criticality for first time in Japan in August, 1957. The JRR-1 was operated for training of scientists and technicians in reactor physics, various experiments in nuclear physics, and experimental productions of radioisotopes. Having finished its initial role, the JRR-1 was permanently shut down in September 1968.

After notification of dismantling for the JRR-1 was submitted to the Science and Technology Agency (STA, current the Ministry of Education, Culture, Sports, Science and Technology (MEXT)) on 20th October 1969, dismantling

Table 1. Outline of research reactors in the NSRI of the JAEA (as of October 2014).

Facility	***Type***	***Power (thermal)***	***First criticality***	***CL***	***MD***	***MNF (n/cm^2)***
JRR-1	Water boiler	50 kW	1957.08	H_2O	H_2O	1.2×10^{12}
JRR-2	Tank	10 MW	1960.10	D_2O	D_2O	1.3×10^{14}
JRR-3	Tank	10 MW	1962.09	D_2O	H_2O	3.0×10^{13}
JRR-3M [1)]	Pool	20 MW	1990.03	H_2O	H_2O	3.0×10^{14}
JRR-4	Pool	3.5 MW	1965.01	H_2O	H_2O	7.0×10^{13}
NSRR	TRIGA-ACPR	23 GW[2)]	1975.06	H_2O	H_2O ZrH	1.9×10^{12}

[1)] JRR-3 was modified to improve its performance as JRR-3M; [2)] Pulse operation;
CL: Coolant; ***MD:*** Moderator; ***MNF:*** Maximum neutron flux (thermal); ***ACPR:*** Annular core pulse reactor.

activities of JRR-1 were started as follows:

Nuclear fuel solution was firstly removed from the fuel drain tank to five cylindrical fuel containers. Gas recombiner water, primary cooling water and secondary cooling water was drained. The reactor tank and the fuel drain tank were washed with rinse water. Valves of system were then closed and sealed after negative pressure. Detectors such as fission counter and ionization chamber were removed and reused in other facility. Instrumentation devices such as neutron detector and thermometer, safety protection circuit and control equipment were cut of the power. After that, high radiation area in the sub-pile room under the reactor core was shielded by concrete blocks. The entrance of the sub-pile room was then locked. Dismantling activities has been completed in March 1970.

JRR-1 has been placed in the safe storage. The reactor room was reused as an exhibition hall in 1978. Figure 1 shows the JRR-1 monument in the exhibition hall.

Figure 1. The JRR-1 monument in exhibition hall.

Notification of abolition of the JRR-1 operation was submitted to the MEXT in July 2003. After that, regulatory classification of JRR-1 was changed from the reactor facility to the nuclear fuel use facility in the Reactor Regulation Law in June 2003.

3. The JRR-2 Decommissioning [3-9]

The JRR-2 attained criticality on 1st October, 1960 and continued operation until 1996 for neutron scattering experiments, irradiation tests of nuclear fuels and materials, radioisotope productions, boron neutron capture therapy (BNCT), etc.

The JRR-2 was permanently shut down after 36 years of operations on 19th December, 1996 because its purpose was achieved and it was decided that the BNCT was continued in JRR-4 after remodel of it.

Notification of dismantling for the JRR-2 was submitted to the STA in May, 1997. Figure 2 shows the JRR-2 reactor body before dismantling. Then, dismantling activities were started in August 1997. As of 2014, JRR-2 has been placed in the safe storage.

Figure 2. The JRR-2 reactor body before dismantling

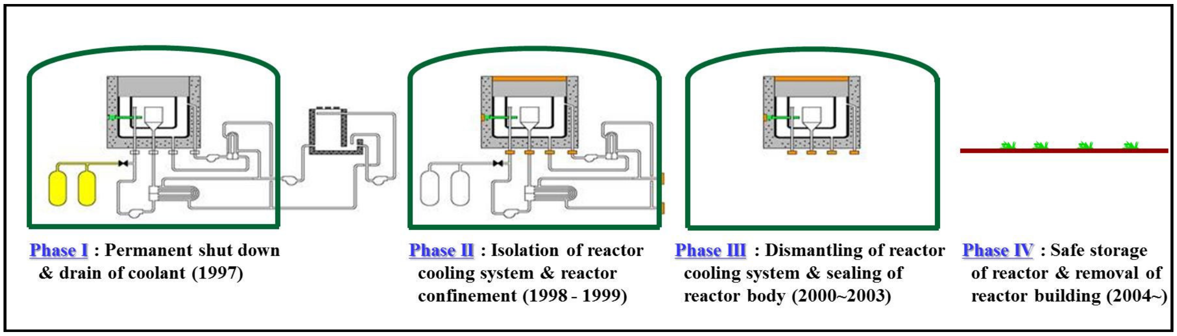

Figure 3. Procedure of the JRR-2 decommissioning

3.1 The JRR-2 decommissioning program

The JRR-2 decommissioning program was divided into 4 major phases as follows:

- *Phase I*: Reactor permanent shut down and drain of coolants;
- *Phase II*: Isolation of reactor cooling system and reactor confinement;
- *Phase III*: Dismantling of reactor cooling system and sealing of reactor body;
- *Phase IV*: Safe storage of reactor body and removal of reactor building.

Figure 3 shows procedure of the JRR-2 decommissioning.

3.1.1 Phase I (1997)

Fuel elements were moved from the reactor core to the spent fuel storage pool (SFSP) and were sent to USA after storing into transportation casts.

Permanent shutdown was executed by removing the control rod drive mechanism. Light water of about 9 m^3 in the thermal shield coolant system was drained in liquid waste storage tanks after filtering and refined by a resin tower. Heavy water of about 16 m^3 in the reactor tank and the primary coolant system was drained in heavy water storage tanks in the JRR-2 or the JRR-3 in 1997.

3.1.2 Phase II (1998-1999)

As main activities of phase II, activities (isolation of reactor cooling system and reactor confinement) to keep the reactor body safely for a long period and transportation of heavy water to Canada were performed.

(1) Isolation of reactor cooling system

Isolation of the reactor cooling system has been executed from January 1999 to March 1999. Pipes were cut off from the reactor body at ceiling of the heavy water pump room set up just under the reactor body. Cut off pipes were those of the primary cooling system (heavy water, helium), the thermal shield cooling system and the irradiated air system connected to the reactor body. Ventilation ducts were cut off in the reactor room. Cutting parts of the reactor body side were then sealed up by welding aluminium seal caps which was the same material as the pipes and the ducts.

The heavy water pipes were treble structure. Double pipe, pipes of inside and outside were that of each heavy water and thermal shield light water, were connected to the reactor tank through the sleeve pipe. The gamma-ray streaming were caused in internal and gap of pipes for that, and dose rate in space just under the reactor included the cutting parts became high (max. 30 mSv/h). Therefore, aluminium seal caps were used as shielding material for gamma-ray from the reactor tank. Aluminium shields of column or arc shape were each inserted into inside and gap of pipes. The thickness of aluminium shields were 1.2 m. Dose rate at the cutting part was lowered to 0.02 mSv/h. Additionally, the gamma-ray streaming was completely shielded by attaching lead plate under aluminium seal cap. As a result, the reactor body could be isolated from the reactor cooling system.

(2) Reactor confinement

Shieldings for horizontal experimental holes, the thermal column and the experimental facilities installed in the pneumatic dispatch tube and the irradiation chamber for the BNCT around the reactor body were removed. The JRR-2 had vertical experimental holes on top and horizontal experimental holes on side of the reactor body. In addition, the JRR-2 had some openings for cable ducts and valve boxes mounted on top, some openings for cable ducts and exhaust ducts mounted on side of the reactor body.

The openings and the experimental holes on top and side of the reactor body were sealed up by welding aluminium seal plates which were the same material as outside plate of the reactor body. Total welded seal plates were approximately 300. Additionally, radiation monitoring tubes to monitor dose rate inside the reactor core during safe storage were set up in vertical experimental holes.

(3) Transportation of heavy water
The possession heavy water of the JRR-2 was about 15 m^3. The heavy water was considerably contaminated by tritium, and tritium concentration of the heavy water was 3.5×10^7 Bq/cm^3 (as of January 1999).

The heavy water was refilled in 92 SUS drums (200 L) after purification to remove radionuclides except tritium, and packed severely to ensure safety. Half a dozen drums were stored into a seal box. Two seal boxes were placed in a truck, and transported to the Tokyo Port. The seal boxes were shipped to the Oakland Port in USA. The seal boxes were then moved to the electric power company of Canada by ground transportation in November 1999.

3.1.3 Phase III (2000-2002)

In phase III, pool water was drained and reactor cooling system was removed as follows.

(1) Drain of pool water
The spent fuels were already finished to be transported to the Department of Energy (USA) in June 2001.

Spent fuel handling device was therefore moved from the SFSP into the green house which was temporary structure for preventing spread of contamination during dismantling activities on the reactor room, and dismantled using mechanical cutting tools, and stored into 1 m^3 containers or 200 L drums.

Pool water of about 64 m^3 was drained to liquid waste tanks after removal of equipment in the SFSP. Sediments such as dross and cut pieces were remained in the bottom on the SFSP. The sediments were expected to have been generated by cutting of fuel adapters before the shutdown of the reactor. The sediments were collected by a water pump. Surface dose rate of collected sediments was maximum 6.7 mSv/h. Drained pool water was purified by the purification system. Purified pool water was transferred to the radioactive waste treatment facility in the NSRI using liquid waste trucks.

Top of the SFSP was covered with vinyl sheets for use as a green house. Inner surface of the SFSP was decontaminated by flushing water. Paint on the pool lining was removed using electric sander etc. The surface of the pool lining was repainted by epoxy resin coating after it was confirmed that contamination didn't remain on the inner surface of the SFSP.

(2) Removal of reactor cooling system
Equipment concerning the thermal shield system and the irradiated air system was dismantled in the heavy water pump room or the exhaust fan room of 1st basement floor of the reactor building which was installation place of each equipment.

Then, equipment concerning the heavy water system such as the emergency heavy water storage tank, the primary coolant heat exchanger and the main pumps was dismantled as follows:

First, a large green house, which consists of a dismantling area, a temporary storage area, a decontamination area and a storage area, was installed on the reactor room of 1st floor of the reactor building. A heating decontamination device for tritium contamination was installed in the decontamination area of the large green house. Figure 4 shows the heating decontamination device. The heating decontamination device consists of a blower, a tritium trap, a hot-air dryer.


Figure 4. Heating decontamination device

Afterward, decontamination of the primary cooling system concerning the heavy water system was executed by the heating decontamination device. Equipment was removed from the installation place, move to the dismantling area of the large green house. Removed equipment was cut from 200 kg to 400 kg, and stored into 1 m^3 containers for heating decontamination. Decontamination using the heating decontamination device is a batch method of max. 400 kg per once. Removed equipment was dried by a hot air of 300 to 400 degrees Celsius for 2 hours using the heating decontamination device. Contamination (maximum 750 Bq/g) of main heavy water heat exchanger tubes was reduced to maximum 2.5 Bq/g by decontamination activities.

3.1.4 Phase IV (2004~)

The JRR-2 reactor body has been placed in the safe storage from 2004. Radiation monitoring tubes to monitor dose rate in the reactor inside in safe storage period were set up in vertical experimental tubes. Dose rate in the reactor inside has been measured once a year. Figure 5 shows the reactor body of the JRR-2 during safe enclosure.

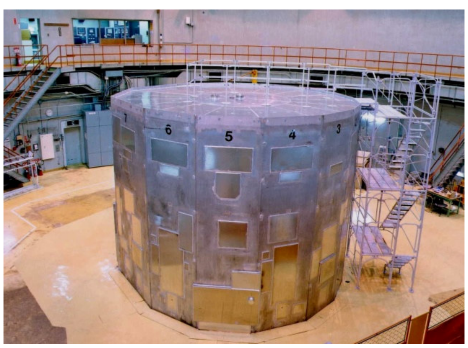

Figure 5. The JRR-2 reactor body during safe storage

The reactor body will be removed after starting to operate the low level waste disposal facility of the JAEA. Remained equipment and components will be then removed after removal of the reactor body. The reactor building will be demolished finally.

4. The JRR-3 Decommissioning [10-14]

The JRR-3 attained criticality in September 1962 and continued operating until 1984. During operation, it contributed to neutron beam experiments and isotope productions. Figure 6 shows the reactor body of the JRR-3 before dismantling.

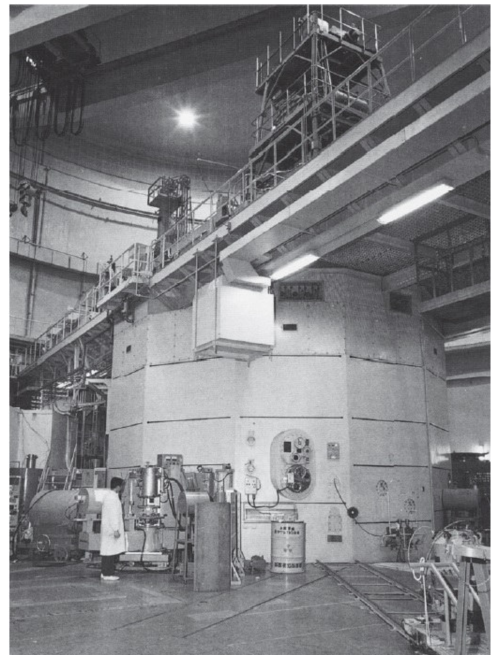

Figure 6. The JRR-3 reactor body before dismantling.

To achieve a requirement for higher flux capability, the JAERI decided the JRR-3 should be reconstructed to further enhance the experimental capabilities in 1984. The decision was made to remove the reactor body in one-piece to the adjacent storage location.

One-piece removal of the JRR-3 was carried out as follows: the reactor cooling system was disconnected from the reactor body. Concrete cores were drilled concrete floor around the reactor body to separate the reactor block from the building structure. The reactor block was transported out of the reactor building using a lift frame, through a temporary opening to the storage space in the temporary shelter. Figure 7 shows outline of one-piece removal of the reactor body of the JRR-3.

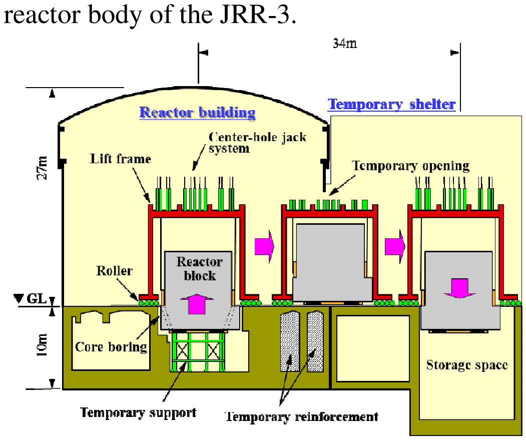

Figure 7. Outline of on-piece removal
of the JRR-3 reactor body

4.1 Disconnection of reactor cooling system from the reactor body

The heavy water (3.7×10^7 Bq/cm^3, tritium) of reactor cooling system was first drained. The pipes of reactor cooling system were then flushed with light water. The pipes were cut away from the reactor body using conventional tools. The pipes were completely filled with resin and sealed with steel alloy plates on the outside wall of the reactor body.

Before the separation of the reactor body, 16 temporary supports (Wide flange beam: 300×300×10×15 mm) were installed under the slab structure, which was the deepest part of the removal reactor body, in order to support the separated reactor block weight from the beginning of the core boring process to the beginning of the jack-up process.

4.2 Core boring process

Cement mortar was grout inside of pipes embedded in drilling positions of the core boring process before core boring process in order to prevent leakage of cooling water for core boring and to prevent damage of cutting edge of core boring.

The reactor body was separated from the building structure using core boring machines (φ150 mm). Three kinds of core boring process were carried out; core boring for suspension, horizontal concrete cutting and vertical concrete cutting.

Three core boring machines (Concrete coring company, Inc. 400 Hz air cooling motor, 400 Hz water cooling gear) were placed symmetrically for horizontal concrete cutting, and were operated with precision control of the cutting depth. Cooling water of the core boring machines was re-circulated to reduce the volume of radioactive liquid waste. Horizontal concrete cutting: core boring horizontally to make space for installing anchorage hardware to lift up reactor block.

The reactor body was separated from the building structures by continuous vertical concrete cuttings of the 3 m thick floors around the reactor body. Vertical concrete cuttings were performed by 7 core boring machines.

4.3 Transportation of the reactor block

One-piece removal system consists of jack up &down system, lift frame, horizontal transportation system. The lift frame was installed around the reactor body before vertical concrete cuttings. Table 2 shows specification of the one-piece removal system.

The reactor block (ca. 2,250 tons) was jacked-up by controlling the jack stroke equalizers and sub-cylinders devised to distribute load to each jack uniformly and by monitoring the axial force at 12 points of the lifting rods. Figure 8 shows the suspended reactor block with the lift frame in the reactor building. The suspended reactor block with the lift frame was transported horizontally to a location above the storage space in the temporary shelter at rate of 5 m/d. During the horizontal transportation, the propelling force (about 80tons) and the strokes of lateral jacks were controlled and the straightness of the lift frame was monitored by the laser theodolite. The lift frame carrying the reactor block was fixed by stops. The reactor block was lowered into the storage space in the temporary shelter with controlled in a similar manner to the jack-up process. The reactor block was lowered to the final position for long term storage. The top opening of the storage space was then closed with reinforced concrete. The reactor block has been placed in the safe storage.

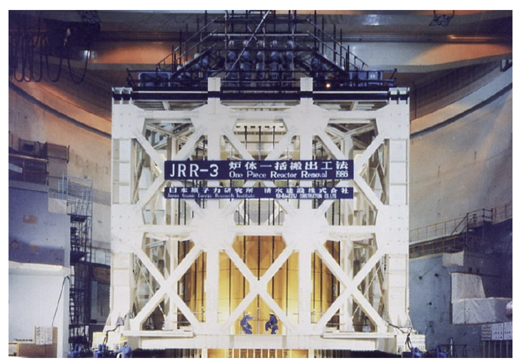

Figure 8. Suspended reactor block with the lift frame in the reactor building during one-piece removal

5. Data Obtained From Dismantling Activities

Management data such as manpower, worker exposure and wastes generation were collected during dismantling activities in the JRR-2 and the JRR-3.

Table 2. Specification of the one-piece removal system.

System	*Item*	*Specification*
Jack up & down system	Center-hole jack system	6×6 (100 ton)
	Load control mechanism	
	6 systems placed in symmetry	
Lift frame	Basket shape with grid beam	Square 12 m on side
	Full brace structure	
Horizontal transportation system	Oil jack for horizontal force application	4 (100 ton)
	Damper between the reactor body and the lift frame	4

Table 3. Manpower and collective dose of workers obtained from dismantling activities in the JRR-2 or the JRR-3.

Reactor	*Phase or work item*	*Manpower (man-day)*	*Collective dose (man-mSv)*
JRR-2	I	851	8.0
	II	2,301	11.3
	III	9,022	4.5
JRR-3	Removal of reactor cooling system	14,300	100.0
	One-piece removal	5,300	0.0

Table 4. Data concerning coring boring to remove the reactor body of the JRR-3.

Work item	*Numbers of coring machine*	*Total coring length*	*Working date*
Horizontal concrete cutting	3	190 m	11 days
Vertical concrete cutting	7	818 m	1 month

Table 5. Data concerning transportation of the reactor block of the JRR-3.

Work item	*Weight (ton)*	*Moving distance*	*Time*
Jacking-up process	2,250	3.7 m	15 hours
Horizontal transportation	2,500 [1)]	33.6 m	7 days
Jacking-down process	2,250	13.5 m	3 days

[1)] Weight include the reactor block and the lift frame

Table 6. Wastes generated from dismantling activities in the JRR-2 or the JRR-3

Reactor	*Phase or item*	*Metal*	*Others*
JRR-2	I	8.0	2.1
	II	226.4	15.2
	III	97.6	31.8
JRR-3	Reactor block	2250.0	
	Others	279.0	428.0

5.1 Manpower and worker exposure

Management data obtained from dismantling activities in the JRR-2 and the JRR-3 were as follows:

Total manpower of dismantling activities until phase III in the JRR-2 was 12,174 man-days. Total collective dose of workers during dismantling activities in the JRR-2 was 23.8 man-mSv.

On the other hand, dismantling activities of the one-piece removal of the JRR-3 were completed in about 19 months requiring 19,600 man-days. Collective dose of workers during the one-piece removal of the JRR-3 was 100 man-mSv.

Table 3 shows manpower and collective dose in each phase or each work item of dismantling activities in the JRR-2 or the JRR-3.

Data concerning core boring to remove the reactor body was obtained during the one-piece removal of the JRR-3 in Table 4. Total coring length was 1,008m to remove the reactor body of the JRR-3.

Data concerning transportation of the reactor block was obtained during the one-piece removal of the JRR-3 in Table 5. Total moving distance of the one-piece removal of the reactor block of the JRR-3 was 50.8 m.

5.2 Wastes generation

Wastes were generated from dismantling activities in the JRR-2 or the JRR-3 in Table 6.

Total weight of wastes generation was 993.5 tons during dismantling activities in the JRR-2. About 38.4% (381.1 tons) of total weight of wastes generation were radioactive wastes. About 87.1% (332.0 tons) of total weight of radioactive wastes were metal.

Total weight of radioactive wastes arising from the dismantling activities in the JRR-3 was 2,957.0 tons. About 23.9% (707.0 tons) of total weight were radioactive wastes without the reactor block.

6. Lessons Learned From Decommissioning of Research Reactors in the NSRI

Lessons learned were gained from dismantling activities of the JRR-1, the JRR-2 and the JRR-3 in the NSRI of the JAEA as follows:

- Decommissioning cost and wastes generation could be reduced to reuse the reactor body of the JRR-1 as the monument.
- Dose rate of the cut parts was high after cutting of heavy water pipes in the JRR-2 because of gamma-ray from the reactor tank. However, dose rate of the cut parts could be reduced due to installation of aluminium shield and lead cap.
- The reactor body of the JRR-2 could be under safe storage to seal up the openings and the experimental holes by welding aluminium seal plates.
- There was corrosion on the part of aluminium lining in the reactor body outside. Therefore, the welding of seal plates was required preheating by a gas burner.
- Treatment of the heavy water became an important problem to ensure safety under decommissioning.
- Fundamental tests with samples of pipes in the primary cooling system and so on of the JRR-2 were effective to set optimal decontamination conditions before actual decontamination activities in the JRR-2.
- It was effective that the mock-up test using a half-scale model of the one-piece removal system was performed before actual removal of the reactor body of the JRR-3.
- Slurry generated in the core boring was recovered in the storage tank. Amount of radioactive wastes could be reduced by reusing supernatant liquid of the storage tank as cooling water in the core boring.
- It was confirmed that the one-piece removal method was effective in minimizing environmental contamination, radiation exposure of workers and wastes generation.

7. Conclusion

The three research reactors (the JRR-1, the JRR-2 and the JRR-3) in the NSRI of the JAEA were already decommissioned as of now.

Nuclear fuel solution was removed from the fuel drain tank in the JRR-1. Valves of the system were closed and sealed after negative pressure. The JRR-1 has been placed in the safe storage. The reactor room was reused as an exhibition hall including the JRR-1 moment.

Equipment concerning the reactor cooling system in the JRR-2 was dismantled. Dismantled equipment concerning the heavy water system was decontaminated by using the heating decontamination devise for tritium contamination. The JRR-2 has been placed in the safe storage after seal of the openings and the experimental holes of the reactor body.

The reactor body of the JRR-3 was successfully removed by the one-piece removal method. The JRR-3M reactor body was constructed in the original location in the reactor building after removal of the JRR-3 reactor block.

Various kinds of data and experience were obtained through the decommissioning activities of these research reactors in the NSRI of the JAEA.

References

1. Division of research reactor operation, Tokai, JAERI, “Mothball of JRR-1,” Japan Atomic Energy Research Institute, the Japan Atomic Energy Research Institute, JAERI-M 4699 (1972) (in Japanese).
2. S.Takashima, “Dismantling of reactor facility - JRR-1 reactor as an example,” Nuclear Engineering, Vol.22, No.4, p.36-40 (1976) (in Japanese).
3. K.Kishimoto, M.Banba, K.Arigane, et. al., “Decommissioning activity of phase 2 in JRR-2,” the Japan Atomic Energy Research Institute, JAERI-Conf 2000-017, p.273-281 (2000).
4. K.Kishimoto, M.Banba, K.Arigane, “Decommissioning plan and current status of JRR-2,” the Japan Atomic Energy Research Institute, JAERI-Conf 99-012, p.207-213 (1999).
5. K.Kishimoto, M.Banba, K.Arigane, “Decommissioning program of JRR-2,” the Japan Atomic Energy Research Institute, JAERI-Conf 99-006, p.111-116 (1999).
6. M.Baba, “Decommissioning plan and current status of research reactor JRR-2,” Journal of the RANDEC, No.22, p.6-19 (2000) (in Japanese).
7. M.Nakano, H.Okawa, T.Suzuki, et al., “Present status of JRR-2 decommissioning,” Journal of the RANDEC, No. 30, p.11-24 (2004) (in Japanese).
8. M.Nakano, K.Arigane, H.Okawa, et al., “JRR-2 decommissioning activity (1),” the Japan Atomic Energy Research Institute, JAERI-Tech 2003-072 (2003) (in Japanese).
9. T.Suzuki, M.Nakano, H.Okawa, et al., “JRR-2 decommissioning activity (2),” the Japan Atomic Energy Research Institute, JAERI-Tech 2005-018 (2005) (in Japanese).
10. N.Onishi, A.Kanenari, Y.Futamura, et al., “Investigations related to a one-piece removal of the reactor block in the frame of the JRR-3 reconstruction program,” Proceeding of the 1987 Internatonal Decommissioning Symposium, Pennsylvania, US, CONF-871018-Vol.2, VI-95-105, October (1987).
11. M. Watanabe, S. Taniguchi, K. Sugihara, “One piece reactor removal system,” Proceedings of second international symposium on demolition and reuse of concrete and masonry,” Chapman and Hall, London and New York, Vol.1, p.493-499 (1988).
12. N.Onishi, “One-piece removal of JRR-3 reactor block,” Journal of the Atomic Energy Society of Japan, Vol.29, No.7, p.19-28 (1987) (in Japanese).
13. N.Onishi, M.Suzuki, T.Nagase and M.Watanabe, “One-piece removal of JRR-3 reactor,” Journal of the RANDEC, No.1, p.46-55 (1989) (in Japanese).
14. M.Suzuki, K.Ito, M.Ogawara, et. al, “Removal of reactor cooling system in JRR-3 reconstruction work,” Journal of the RANDEC, No.2, p.41-49 (1990) (in Japanese).