

DECOMMISSIONING PROGRAMS AND TECHNOLOGY DEVELOPMENT IN JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

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ABSTRACT

Several research facilities including a nuclear power plant have been decommissioned to date in the Japan Atomic Energy Research Institute so that the experience on decommissioning was effectively accumulated through these decommissioning projects. The research and development program has also been continued focusing on efficiency of dismantling activities and minimization of waste arising, which will be applied to future decommissioning of commercial nuclear power plants as well. Computer code systems for planning of decommissioning activities and simulation of remote dismantling have been developed based on the experience of the first decommissioning of a nuclear power plant, in which the various data were systematically collected to characterize dismantling activities. The R&D program and the experience on decommissioning nuclear facilities in JAERI will be described in this paper.

INTRODUCTION

The Japan's first nuclear power plant, the Japan Power Demonstration Reactor(JPDR) went into operation October, 1963 in the Japan Atomic Energy Research Institute (JAERI), followed by the commercial operation of the Tokai Power Station in July 1966. Since then, the number of nuclear power plants increased to 51 with electricity supply of about 45 Gwe by March, 1998(1). However, it is expected that 10 nuclear power plants will be operated for more than 30 years at the time of year 2005.

On the other hand, JAERI has played a role as a research center contributing to atomic energy development and its utilization in such a way of nuclear power plants, application of radioactive isotopes and fundamental nuclear science. Consequently, a number of experimental nuclear facilities were constructed in JAERI; some of the old facilities have been shut down after completion of their initial purposes. So far, research reactors, the Japan Research Reactor Nos.1 and 3 (JRR-1 and 3), and the Nuclear Ship Mutsu were already decommissioned. A part of the JRR-1 facility was reformed to be a memorial place in JAERI. Completion of the JPDR decommissioning program in March 1996 was a main fruit of decontamination and decommissioning (D&D) activities in recent years(2). Know-how and data on project management in decommissioning nuclear facilities were collected in the JPDR dismantling activities. The data on dismantling activities were analyzed to characterize the JPDR dismantling activities for future decommissioning of nuclear power plants and other nuclear facilities as well. The JAERI Reprocessing Test Facility (JRTF) and the Japan Research Reactor No. 2 (JRR-2) decommissioning programs are the current D&D activities in JAERI. These programs have been conducted by reviewing the experience of the JPDR decommissioning program. The D&D technologies have been also developed to perform dismantling activities rationally with safe and economical manner. The systems engineering approach by development of computer tools for planning of decommissioning activities, wide usable remote handling devices, and decontamination techniques are the major items to be studied in the program.

Table 1 Decommissioning projects in JAERI

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- ☐ **Japan Power Demonstration Reactor (JPDR) [Dismantling]**
 - Phase I : 1981 - 1986 (R&D)
 - Phase II : 1986 - 1996 (Dismantling)
 - Phase III: 1996 - 2000 (R&D)
 - ☐ **JAERI Reprocessing Test Facility (JRTF) [Dismantling]**
 - Phase I : 1990 - 1996 (R&D)
 - Phase II : 1996 - 2004 (Dismantling)
 - ☐ **Japan Research Reactor No.2(JRR-2) [One-piece removal]**
 - 1997 - 2007
 - ☐ **Nuclear Ship Mutsu (NS Mutsu) [One-piece removal]**
 - 1993 - 1995
 - ☐ **Japan Research Reactor No.3 (JRR-3) [One-piece removal]**
 - 1981 - 1987
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The D&D programs and technology development in JAERI will be described in this paper.

BACKGROUND

Decommissioning of nuclear power plants might be possible using conventional and partially improved technologies. However, development of D&D technologies is desirable from economical and safety points of view. The Japanese policy of decommissioning nuclear power plants is to dismantle the facilities in relatively short period after its permanent shutdown for reusing the site to the next nuclear power plant. The research and development for decommissioning nuclear power plants have therefore been carried out by government organizations under contract with the Science and Technology Agency or the Ministry of International Trade and Industry in Japan. JAERI has been conducting the demonstration decommissioning programs targeting nuclear power plants and non-reactor nuclear facilities to verify the technologies developed for decommissioning. Table 1 lists the decommissioning programs conducted by JAERI until now. The JPDR and the JRTF facilities have been used for verification of the technologies by actual use in their dismantling activities. In addition, decommissioning of research reactors is one of the important issues in research organizations in the world. Since all radioactive waste arising from research activities and dismantling of nuclear facilities should be stored in the storage facilities in JAERI until disposal facility will be constructed. One piece removal method is practical and it is considered as one of the options for minimizing radioactive waste arising from decommissioning research reactors.

DECOMMISSIONING PROGRAMS IN JAERI

JAERI Reprocessing Test Facility

The Japan Atomic Energy Research Institute's Reprocessing Test Facility (JRTF) was constructed 1966 as the first test facility for fundamental studies on PUREX fuel reprocessing in Japan. The JRTF was operated from 1968 to 1969 and reprocessed the spent uranium/aluminum metal fuels of the Japan Research Reactor No.3 (JRR-3). About 200 g of pure plutonium was recovered by successful operation of the facility. The JRTF was shut down 1970, and a part of the facility has been kept open and used for the studies on the measurement of fuel burn up ratio, treatment of liquid waste, and others.

The JRTF consists of a main building and two annex buildings. The main building was used for reprocessing of spent fuels. It has four levels of which total floor area is about 3,000 m². The main components in the building are the main cell, the plutonium purification cell, the solvent recovery cell and the eleven lead cells (1m³ volume in each). There remaining are the dissolves and pulse columns in the main cells, the concentrator and the mixer-settlers in the plutonium purification cell, the solvent washing decanter in the solvent recovery cell.

In consideration of future decommissioning of no-reactor nuclear fuel facilities, it was decided 1990 to use the JRTF as a demonstration project by dismantling it into green field condition. Since some liquid waste is remaining in the facility, treatment of the liquid waste in storage tanks is necessary for start of dismantling activities. The JRTF decommissioning program therefore includes treatment of liquid waste, research and development of dismantling techniques and actual dismantling activities. Efforts were made to develop several technologies such as protective suite for alpha contamination, three dimensional image drawing systems, laser decontamination. Approximately 430 tons of radioactive waste are estimated to be produced from the dismantling activities.

Japan Research Reactor No.2

The Japan Research Reactor No.2 (JRR-2) is a heavy water moderated and light water cooled type research reactor. It used high enriched uranium fuels to obtain neutron flux of 1.8×10^{14} with 10 MW thermal output. It attained criticality in October, 1960 and continued operation until 1984 for neutron scattering experiments, irradiation tests of nuclear fuels and materials, radioisotope production, boron neutron capture therapy, etc. The JRR-2 was finally shut down due to degradation of components after 36 years of operation. The JRR-2 decommissioning project started in August, 1997. The project was divided into 4 major phases; shutdown activities, reactor safe storage, dismantling of cooling systems and removal of reactor body, and it will be completed by 2007. Since one-piece removal method was successfully applied to other small reactor facilities such as the JRR-3 and Nuclear Ship Mutsu, it will also be applied to dismantling of the JRR-2. The reactor blocks including core components and biological shield structures were removed from the original location in one piece for long-term storage on site. This is not considered to be disposal as the items will eventually be sent to the final repository. The building will be reused for hot laboratory experiments.

Table 2 Outline of the JPDR dismantling project

Plant Characteristics

Reactor type & power	: BWR, 45/90 MWt
Facility operation period	: 1963 - 1976
Total output power	: 21,500 MWD

Dismantling Project Overview

Project period	: Dec. 1986 - Mar. 1996
Project cost	: 23 billion yens(including R&D)
Waste arisings	: 3,770 tons (Radioactive)
Worker dose	: 306 person - mSv

Japan Power Demonstration Reactor

The JPDR decommissioning program began in 1981. It was divided into two phases; technology development (1981-1986), and actual dismantling (1986-1996). Various technologies for reactor decommissioning were developed in the first phase (3,4). The developed technologies were applied to the actual dismantling of the JPDR in the second phase. The remote dismantling work for reactor core part was conducted from the center to outer part of core components and structures. The underwater plasma arc cutting system was applied to removal of the reactor internals. The plasma torch was operated by either mast-type or master-slave manipulator. The reactor pressure vessel was successfully cut by the underwater arc saw cutting system. The concrete biological shield was dismantled by abrasive water jet and mechanical cutting. The controlled blasting method was applied to dismantling the concrete biological shield of extremely low radioactivity. Data on project management such as manpower expenditure, waste arisings, worker dose were systematically collected in the dismantling activities. The data was analyzed to characterize the dismantling activities. Table 2 depicts the outline of the JPDR decommissioning program.

TECHNOLOGY DEVELOPMENT

In the JPDR decommissioning program, various D&D technologies had been developed over 8 items in systems engineering, radioactive inventory estimation, decontamination, dismantling, remote handling, etc. For example, a computer code system for management of reactor decommissioning (COSMARD) was developed to aid the analysis of work procedures and the selection of the most appropriate mode of dismantling activities(5,6). The project management data was estimated in terms of radiation exposure of workers, manpower needs to evaluate effective dismantling practice and use in the dismantling analysis report. During and after the dismantling of the JPDR, data was collected and analyzed to be used for verification of the code systems. The dismantling project itself was also reviewed from view points of technology, project management, waste management, etc. The research and development of

D&D technologies has then started on the basis of reviewing the technologies applied to the dismantling activities. The main items of the research and development program are as follows.

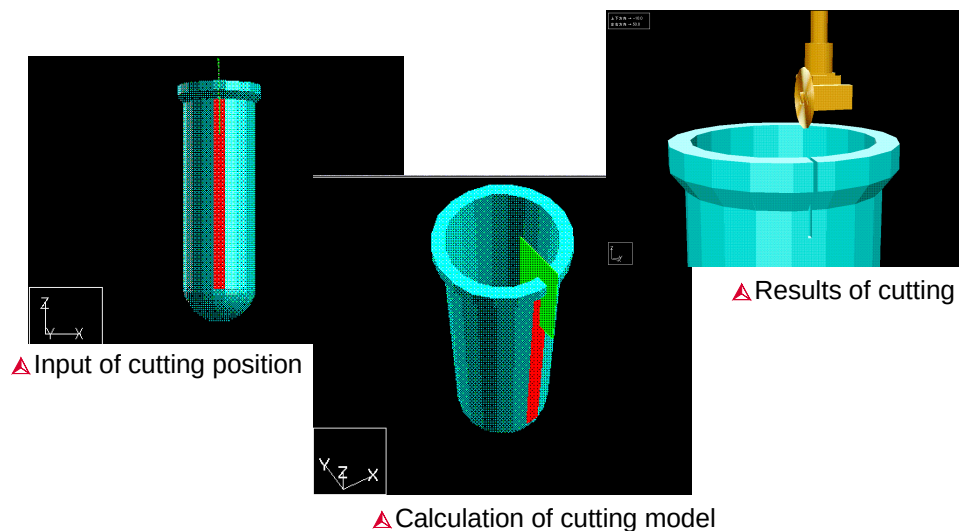


Fig1 An example of kinematic analysis (cutting of reactor pressure vessel)

- Remote dismantling technique with wide application
 - General purpose remote handling devices
 - Computer simulation of work environment and remote dismantling
- High-performance decontamination technique
 - In-situ remote decontamination
 - Laser induced chemical decontamination process
- Radioactivity measurement and plant information collection technique
 - Measurement of low radioactivity on building surface
 - Measurement of radioactivity inside of pipes
- Systems engineering approach for evaluation of decommissioning plan
 - Knowledge-based planning and evaluation systems
 - Integrated decommissioning database

Though the review of dismantling activities, especially usefulness of information integration was pointed out for minimizing waste and radiation exposure of workers as well as efficient project execution. The review resulted in developing the computer simulation systems for analyzing optimum dismantling procedures. Various kinds of information are necessary for optimization of dismantling activities. The computer simulation program was designed to integrate information on dismantling procedure, plant physical and radiological characteristics, control of handling tools, etc. Figure 1 is an example of computer simulation on a computer screen showing kinematic analysis on movement of remote dismantling machines(7).

The general purpose remote handling devices, which are dual arm manipulators, have been developed to be connected with the computer simulation systems to realize the motion tested by the systems on the computer screen. This system will be applied to dismantling of components in the JRTF facility after testing the capability of this system in non-radioactive conditions.

FEEDBACK OF EXPERIENCE TO FUTURE PROJECTS

Experiences on the actual dismantling work in JAERI should be very important if they would be transferred effectively to future decommissioning projects. The methodology for effective feedback of the experiences should be studied in a practical way. Through the JPDR decommissioning program, it was recognized that the data on dismantling activities and machine performance was useful for conducting the dismantling project efficiently. Consequently, the analysis on the project management data started to characterize the JPDR dismantling activities. The database have been also developed by analyzing the data on the dismantling activities together with preparing of its report. The data was analyzed from three different viewpoints of waste arising, productivity and safety. The performance of the dismantling machines and productivity were analyzed to be included in decommissioning database. Figure 2 shows an examples of the database relating to the dismantling machines performance, that is, the data on dismantling reactor internals by underwater plasma arc cutting. Since the thermal cutting such as underwater plasma arc cutting and arc saw cutting required the treatment of by-products, additional manpower was necessary for treatment of dross and aerosols. On the other hand, solidification of concrete by-product, which produced in cutting of biological shield was necessary for appropriate waste management.

Through the data analysis on the JPDR dismantling activities, unit productivity factors, that is, relationships between manpower need and certain indexes such as weight of components to be dismantled and area size were developed to be applied to estimation of manpower need in future dismantling of nuclear facilities. Figure 3 shows an example of unit productivity factors developed by analyzing the data on the JPDR dismantling activities. Manpower need relating to preparatory and cleanup activities was defined by selecting the proper values from the five groups.

Plasma arc cutting is a thermal cutting method in which arc and plasma gas heat is produced by electrical current between arc node and object to be cut. By-product treatment is necessary for worker safety.

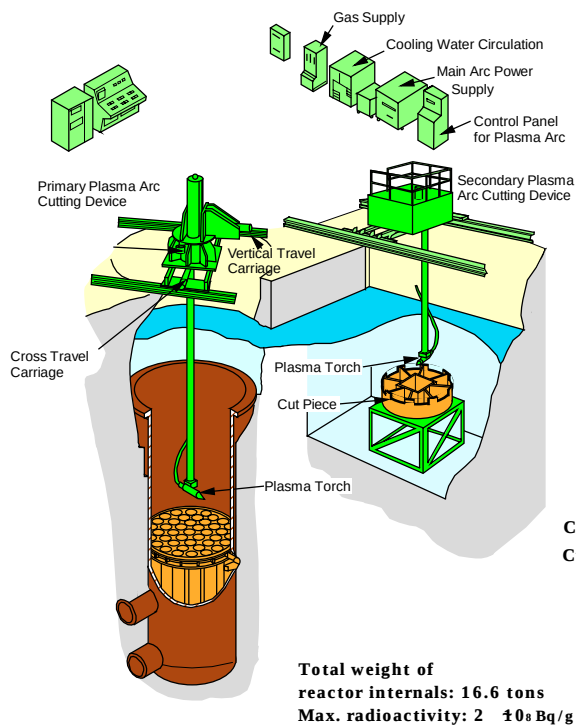


Slave arm (manipulator) Mast-type remote handling machine

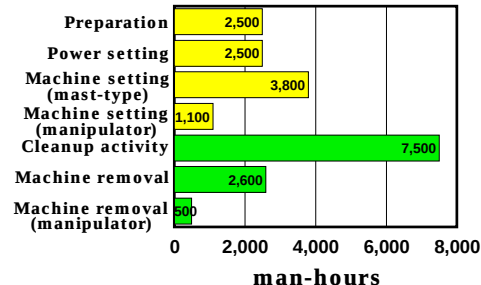
Cutting capability (stainless steel)

Max thickness 230mm, Cutting speed 50mm/min (in air)

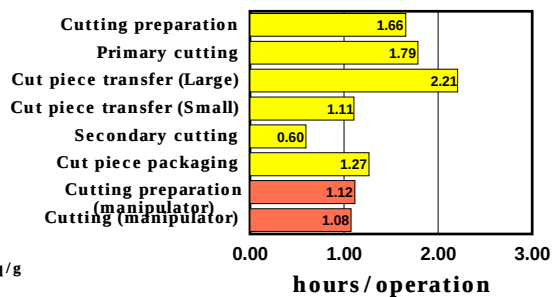
Max thickness 130mm, Cutting speed 75mm/min (underwater)



Manpower Need



Unit Productivity Factors



Mast Type Plasma Arc Cutting System

Fig. 2 An Example of database on JPDR dismantling activities (Dismantling of reactor internals by underwater plasma arc cutting)

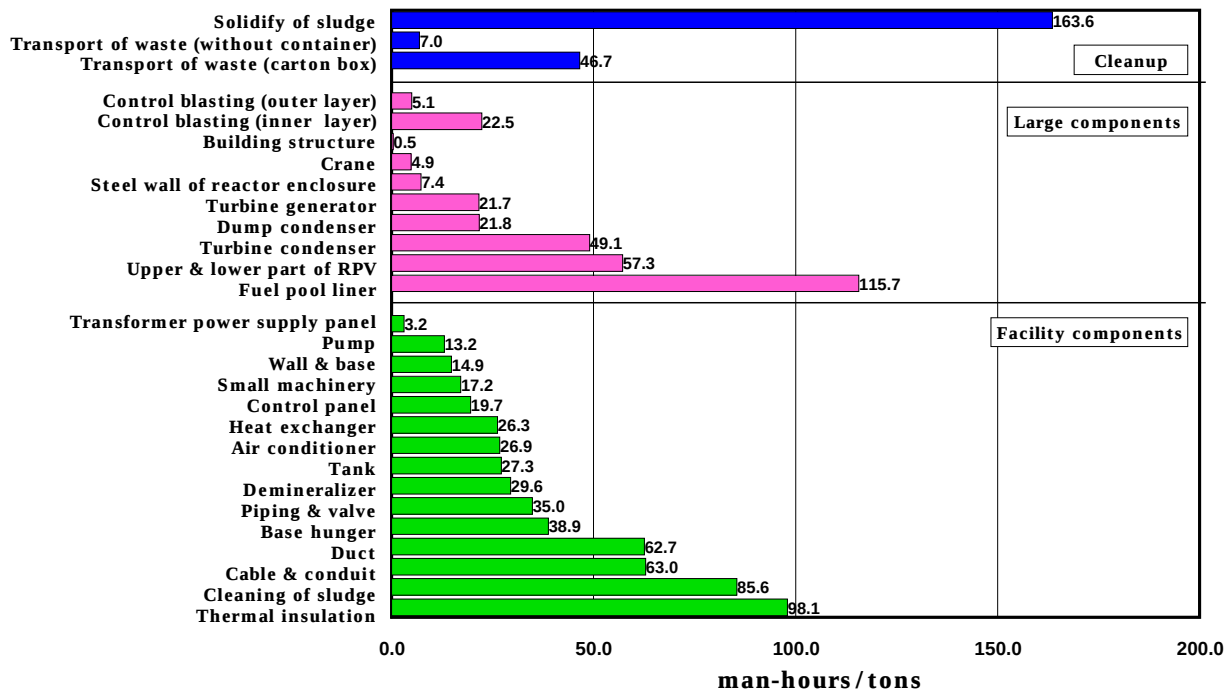


Fig. 3 Unit Productivity Factors of Hands-on Dismantling Activities

CONCLUDING REMARKS

The Japan's first decommissioning project of a nuclear power plant (JPDR) was successfully completed 1996 followed by decommissioning of a commercial nuclear power plant. The experience and data obtained from the JPDR dismantling project will be utilized for decommissioning commercial nuclear power plants in the future. In addition, the decommissioning programs for JRTF and JRR-2 are under way in JAERI. The data obtained from these activities will be expected to be useful for future decommissioning of nuclear facilities. The technology development on D&D was also in progress, which has been conducted by reflecting the experience of dismantling nuclear power plant. Information integration, effective designing of dismantling activities by computer tools were recognized to be useful for conducting a dismantling project in economical way. The database was also developed for future decommissioning of nuclear facilities in JAERI and commercial nuclear power plants as well.

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References

(1) Tanaka, M., et al.: The Japan Power Demonstration Reactor Decommissioning Program –

Overview and lessons learned-, Nuclear Plant Journal, July-august, 1997

- (2) Miyasaka, Y., et al.: Results and Outline of JPDR Dismantling Demonstration Project, J. At. Energy Soc. Japan, Vol.38, No.7, pp.553-576(1996)
- (3) Yanagihara, S., et al.: Dismantling techniques for Reactor Steel Structures, Nucl. Technol., Vol.86, August, pp.148(1989)
- (4) Nakamura, H., et al.: Cutting Technique and System for Biological Shield, Nucl. Technol., Vol.86, August, pp.168(1989)
- (5) Yanagihara, S., et al.: Systems Engineering for Decommissioning the Japan Power Demonstration Reactor, JSME Int. J., se. B, 36(3), 494(1993)
- (6) Yanagihara, S., et al.: COSMARD – Code System for Management of JPDR decommissioning, J. Nucl. Technol., 30(9), 89(1993)
- (7) Tachibana, M., et al: Computer Simulation Systems for Analyzing Optimum Dismantling Procedures on Nuclear Facilities, Pro. 6th Int. Conf. On Radioactive Waste Management and Environmental Remediation, Singapore, 1997