EXPERIENCES OF REMOTE OPERATED DISMANTLING OF GLOVE-BOX

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ABSTRACT

The Japan Nuclear Cycle Development Institute (JNC) has a glove-box (GB) dismantling facility (GBDF) in the Plutonium Fuel Production Facility. Some GBs for the MOX fuel fabrication process had been dismantled in the GBDF using the direct dismantling method that is done by workers equipped with protective equipment including an air supply. Additionally, GBDF has remote control apparatuses, such as manipulators. The manipulators had been used for assistance purposes and carried out a small remote operated dismantling examination. This time, a remote operated dismantling of a whole GB that was $9m^3$ volume was conducted by them. It was confirmed that the dismantling activities, which consist of removal of the glove panel, dismantling of the interior equipment and dismantling of the GB body and made up about 45% of the overall dismantling of GB in the GBDF, could be adequately performed by remote control. The working efficiency of remote operated dismantling work is approximately comparable to the efficiency of direct dismantling work. It revealed additional concerns to be examined so that the GB remote operated dismantling activity could be improved. JNC is considering a remote operated dismantling of GB method as one possible solution for the advancement of safe and effective GB dismantling technology as part of the decommissioning of the nuclear fuel facility.

INTRODUCTION

In the Japan Nuclear Cycle Development Institute (JNC) Plutonium Fuel Center, the glove-box (GB) dismantling activities have been done for years for replacement of the equipment used for mixed oxide (MOX) fuel production. Conventional GB dismantling activity is done by workers equipped with personal protective equipment (PPE), including an air supply. They disassemble and cut a GB to a suitable size in a plastic enclosure tent for contamination expansion prevention in the circumference of the GB. This is GB dismantling using the direct dismantling method. In order to prevent an inhalation contamination, the workers are equipped with PPE, and wear several over-suits and overshoes. Moreover, they wear 5-7-fold RI rubber gloves, and use protective gloves made of leather. Although personal radioactive security is maintained with this equipment, they tend to sweat excessively and become exhausted. For this reason, the daily working hours for a worker equipped with PPE are limited to 1 or 2hrs in consideration of personal radioactive security and workload on the body. Therefore, the actual working hours of those workers directly involved in the dismantling work are brief, often limited to a few hours a day. The direct dismantling work requires many assistant workers who mainly do the decontamination work for the main worker's PPE surface. The number of assistant workers is several times higher than the number of main workers. Moreover, there is considerable cutting activity, and the direct dismantling work has an increased danger of injury and contamination and is therefore required to have emergency procedures in place to deal with the management of potential accidents involving contamination. As mentioned above, the direct dismantling work of GB is not very efficient, it requires the use of many workers, the fatigue of the workers is considerable. The decommissioning of the MOX fuel production facility will move forward[1)], while options for the advancement of safe and efficient GB dismantling technologies are required. The JNC is considering a remote operated dismantling of GB method as one possible solution.

Generally in the nuclear fuel facility, since remote control apparatuses are expensive and also require considerable labor and maintenance costs, they are restricted to use in areas of high radiation that workers cannot access easily, such as the hot-cell of reprocessing facilities. Moreover, although remote operating activity is efficient in regular repetitive operations, it does not fit well with irregular operations, such as dismantling work. In these instances it is inefficient. For these reasons, there is little use of remote controlled equipment within MOX fuel fabrication facilities with comparatively few problems of radiation doses. Its GB dismantling work has been carried out almost exclusively by direct dismantling work.

The Plutonium Fuel Production Facility (PFPF) in JNC has automated the MOX fuel fabrication systems, including the use of remote control, for the purpose of demonstrating the industrial production of the MOX fuel. It is composed of many MOX fuel fabrication process glove-boxes (GBMP), which equip the interior of the various fuel fabrication apparatuses with a GB of constant form (3m x 3m x 1m = $9m^3$). Some GBMPs have been separated from the fabrication line and dismantled in the GB dismantling facility (GBDF), which does dismantling work intensively, after they have gone out of service. The GBDF has two contamination control rooms for the PPE equipped direct dismantling workers and has some remote control apparatuses, such as a power-manipulator and a master-slave-manipulator (See Figure 1). It had been performed some GB dismantling by the direct dismantling method. The manipulators had been used for assistance purposes and carried out a small remote dismantling examination[2)]. This time, a remote operated dismantling of a GBMP was conducted by them. The working efficiencies of the remote operated dismantling and the direct dismantling were compared and usefulness of the remote operated dismantling was demonstrated. It revealed additional issues that needed to be addressed in order to improve the GB remote operated dismantling activity.

PERFORMANCE

The constant form GB has eighteen glove panels (1m x 1m, a thickness of 10mm) which has some glove ports, are made from acrylics and are fixed to the GB body with many bolts by nine panels in both forward and backward positions. Its body is composed of a frame and covered by a roof, two sides and sole plate boards which are made from stainless steel in a thickness of 6mm. This time the GBMP conveyance equipment, which conveyed the MOX fuel pellets into roasting furnace, was disassembled. Its interior equipment had a lift and a carrier that moved the pellet trays either sideways or up or down, rails, ball screws, and so on. These were supported by pillars of H shaped steel and C shaped steel (Figure 2).

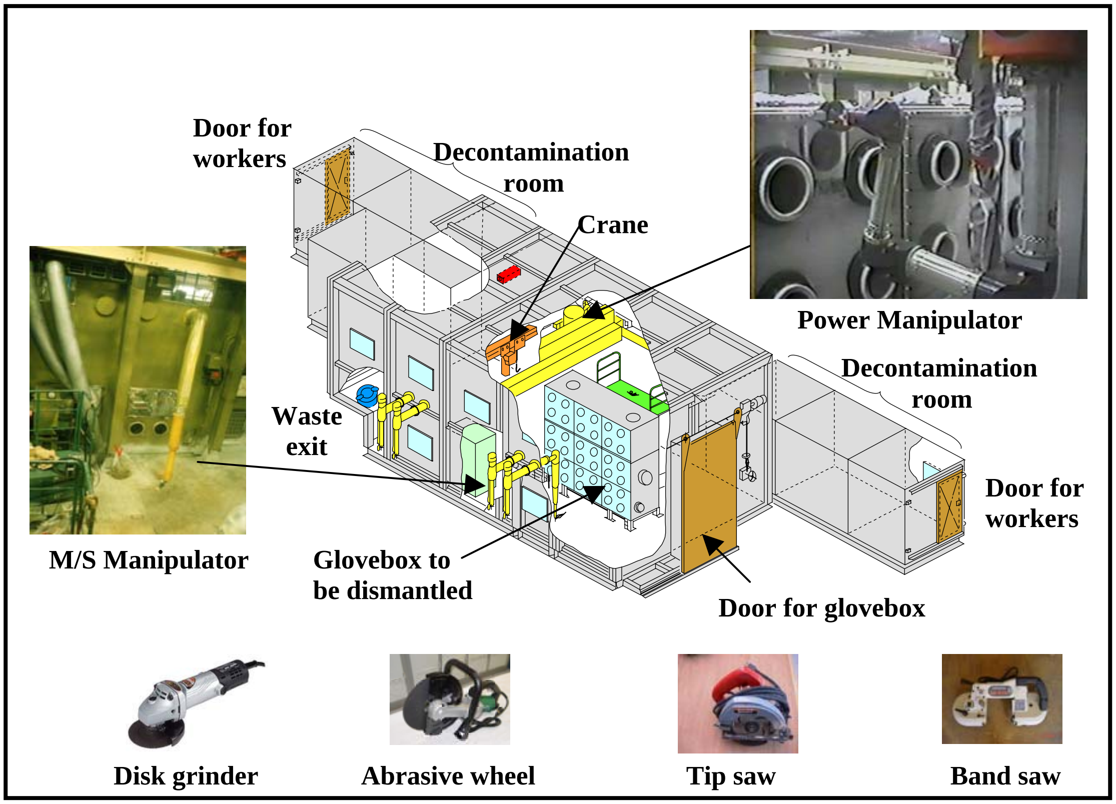

Fig. 1. Glove-Box Dismantling Facility

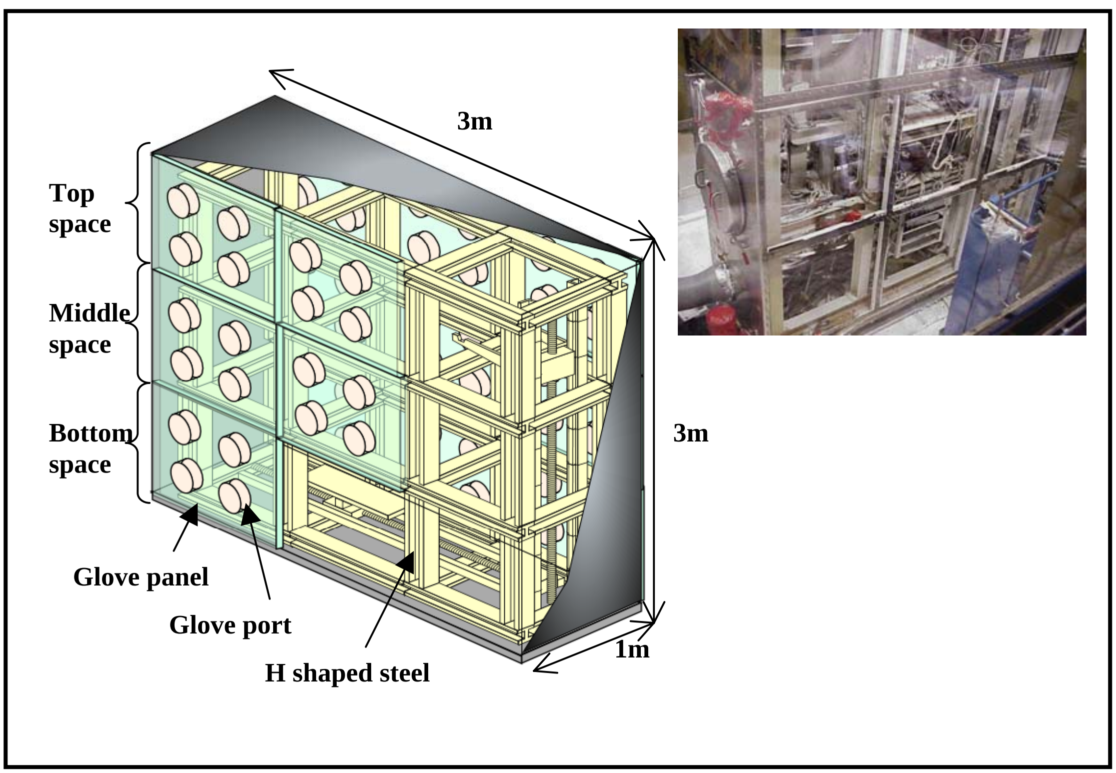

Fig. 2. GBMP with conveyance equipment

The GB dismantling work has been composed of eight activities of which the basic steps for dismantling a GB in the GBDF can be summarized as follows:

1) Preparation   Preparation and Setting after the GB is bagged into the GBDF
2) Removing Panel   Removal of the glove panel
3) Disassembling Panel   Disassembly and size reduction of the glove panels by cutting
4) Cutting Interior   Size reduction of interior equipment by cutting
5) Cutting GB   Size reduction of the GB body by cutting
6) Containment Segregate   Packing, and containment of the segregate into waste containers
7) Maintenance   Maintenance of equipment
8) Clean up   Clean up of GBDF

It was established that some simple tasks, like removal of the bolts of the glove panel and cutting plates, could be performed by remote control. But this time, activities 2), 4) and 5) listed above were carried out by remote control as dismantling works. The outline of these works is as follows.

This GB dismantling work first removed one glove panel at the top of GB, and then involved cutting and removing the interior equipment in a sphere which the manipulator-arm could reach from the opening side. Then, the next glove panel was removed and cutting and removal of the other interior equipment was performed again. Activities 2) and 4) were repeated at the top, the middle and the bottom of the GB divided into three layers. Finally the GB body was cut and removed, and then placed into appropriate waste streams.

A power-manipulator was used mainly for cutting, and two M/S-manipulators and a crane were used to assist or carry the segregates. Power-manipulator: TELBOT/HWM made, 6 articulations, max-load 50kg. M/S-manipulator: A100/HWM made, electric stretch type, max-load 50kg.

The dismantling tools used were commercial electric tools with adapters for fixing on the power-manipulator such as the disk grinder, the tip saw, the band saw, the nibbler and the impact wrench.

RESULTS

The crew of the remote operated dismantling work included eight workers, and was comprised of a leader, an assistant leader, and for each manipulator, an operator and an assistant operator. The removal of the glove panel, the cutting of the interior equipment and the cutting of the GB body were performed by remote control for 34 days. It was confirmed that the remote operated dismantling of the GB was carried out the activities adequately. However, 30% of the interior equipment in the bottom of the GB and 84% of the GB body had not been cut by remote control. Their remaining portions were cut by the direct dismantling method in order to finish this GB dismantling work early. Moreover, the activity of segregate packing and removing for containment into waste containers was performed by the direct dismantling work and the glove work from a couple of glove-ports on the GBDF.

The power manipulator was in operation for about 3.5 hours a day for the purposes of preparing, cutting, removing, exchanging tool and adjustment. Its operation rate is shown in Figure 3, and its main cutting objects and corresponding cutting times are shown in Table I.

Table I. Dismantling Operation Times

	Working Period (days)	Power manipulator operation time (min.)	Cutting & Disassembling time (min.)	M/S manipulator operation time (min.)	Dismantling objects	Cutting rate of H shaped steel (min./part)
Top Space	15	3258	1792	235	Panel, Ball screw, Lift, Carrier, Rail Piping, Rack H shaped steel, etc	31
Middle Space	8.5	1690	903	252	Panel, Ball screw, Lift, Carrier, Rail H shaped steel, C shaped steel, etc	12
Bottom Space	7.5 (70%)	1659	886	535	Ball screw, Lift, Carrier, Rail H shaped steel, etc	8
GB Body	3 (16%)	621	252	210	Roof, Side, Sole plate board	——

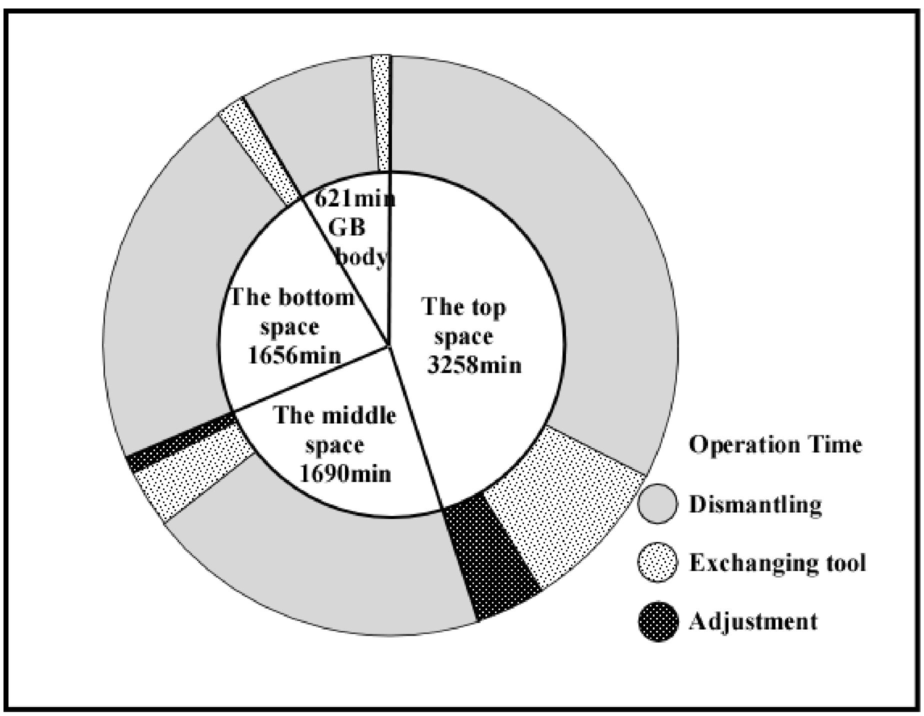

Fig. 3. The Power Manipulator Operation Rate

DISCUSSIONS

The percentage of the remote operated dismantling work

The GB dismantling work in the GBDF consists of eight activities. The rate at which the activities are performed can be estimated from the number of PPE equipped main workers responsible for the direct dismantling work. The actual results of two direct dismantling works are shown in Table II. It shows that the activities are influenced by the skill of the workers, but that the rates at which the activities are performed were approximately comparable. Therefore, the total percentage of the remote operated dismantling activities, which consists of removal of the glove panel, dismantling of the interior equipment and dismantling of the GB body was estimated at about 45% of the GB dismantling in the GBDF.

Table II. The Direct Dismantling Works

GBMP dismantled		Milling process	Grinding process
The skill of the workers		Experts	Beginners
The work periods (days)		30	64
The number of main workers responsible for the GB dismantling activity & (%)	1) Preparation	5.4, (4%)	4, (2%)
	2) Removing Panel	13, (10%)	2, (1%)
	3) Disassembling Panel	1.8, (1%)	4, (2%)
	4) Cutting Interior	21, (17%)	69, (29%)
	5) Cutting GB	20, (16%)	38, (16%)
	6) Containment Segregate	38.7, (31%)	64, (27%)
	7) Maintenance	10.4, (8%)	23, (10%)
	8) Clean up	13.7, (11%)	36, (15%)
	Total	124, (100%)	240, (100%)

The working efficiency

A dismantling activity is composed of various operations and it is not enough to evaluate the working efficiency based on the operation times for cutting only. The working efficiency should be evaluated in terms of the whole operation, which was composed of preparing, cutting and removing operations. It is compared to the working efficiency of the remote operated dismantling work with the direct dismantling work as follows.

In this GB dismantling work, parts of the activities for the cutting of the interior equipment and the cutting of the GB body remain, without operating completely by remote control. The time needed for finishing the remains of these activities by remote control was estimated using the cutting rate and the amount of remains. It was estimated to be 3.5 days for the cutting of the interior equipment at the bottom of the GB and 16 days for the cutting of the GB body. Therefore, in order to operate completely by remote control the activities for removal of the panel, cutting of the interior equipment, and cutting of the GB body, it was thought that the period of 34+3.5+16= 53.5 days was required.

Conversely, the work periods for the same activities in direct dismantling work had been 124men x 45% x 1/2 day/man = 28 days by experts and 240men x 45% x 1/2 day/man = 54 days by beginners. In addition, the direct dismantling work activities had been carried out by about two workers a day.

From these results, it means that the work period of the remote operated dismantling work would be operated for twice as long as the work period of the experts and for as long as the work period of the beginners. Therefore the working efficiency of the remote operated dismantling could be estimated to be 1/2 of experts.

However, since this was an experimental examination of the remote operated dismantling work, the operation time of the power manipulator was short, 3.5 hours a day. If it was operated for 6 hours, the work period would be 53.5 days x 3.5hrs/days / 6hrs/days = 31days, namely the working efficiency of the remote operated dismantling work would be comparable to the efficiency of the direct dismantling work by experts.

Comparison of GB dismantling between the remote operated and manual

At least eleven assistant workers who assist the main worker and mainly decontaminate the main worker's PPE surface would be required for the direct dismantling work each day, and a larger work organization consisting of PPE equipped main workers and assistant workers would also be necessary. On the other hand, the work organization of the remote operated dismantling work could consist of just eight workers a day. For these activities, the remote operated dismantling work would presumably require 248 workers (8 workers /day x 31days). A direct dismantling work by the experts required 364workers (124workers x 45% + 11workers/day x 28days). There are 30 percent fewer workers in the remote operated dismantling work than in the direct dismantling work, so a reduction in cost of GB dismantling work by remote operation can be expected.

The amount of secondary waste generated in the direct dismantling work is dependent on the PPE of workers etc. But in the remote operated dismantling work, since this kind of radioactive waste had not occurred fundamentally, the amount of secondary waste generated was reduced.

Moreover, the workers were safe and were exposed to a reduced dose of radiation in comparison with the direct dismantling work because of remote control. Therefore remote operated dismantling work would result in safe and rational GB dismantling.

Assignment of the remote operability

The interior of the disassembled GBMP was incorporated like a jungle gym by the cart rails and pillars of H shaped steel and C shaped steel. There were approximately similar objects in each space ($3m^3$), the top, the middle and the bottom. However, the operation time required by the power manipulator in the top was twice as long as it was elsewhere (Figure3). Moreover the cutting times when the same shaped objects, H shaped steel etc., were cut by the same cutter varied in different positions. In the top space the work took longer than elsewhere (Table I). This is considered to affect mainly the following three factors.

Operation degrees of freedom of the power manipulator

The power manipulator has been hung from the ceiling rail in the GBDF, and in the dismantling work of the top space of the GB, its arm had been almost always folded up and its operational degrees of freedom and the range of operation had been decreased. Therefore it is thought that the operation time for remote control was increased in the top space.

Contact of peripheral equipment and the cutter

When the interior equipment cutting activity in the top space of the GB was the initial stage of the GB dismantling work, since the GB was filled up with interior equipment, there was almost no space into which a cutter supported by the power manipulator could be put. The direction in which the cutter could be inserted was only one direction perpendicular to the side of the GB. Contact between the peripheral equipment and the cutter blocked the cutter's action. The cutter was able to move freely after equipment on the upper side was removed, which resulted in increased space. It was thought that operation improved and working efficiency improved.

Assistance degrees of M/S manipulators

Since the power manipulator and the M/S manipulators were operated from the sides in which both approached, during the initial stage of the GB dismantling work, the assistance of the M/S manipulators could not be utilized frequently, due to interference with the power manipulator. Since cutting in the middle was improved after equipment on the upper side was removed in order to increase space in the upper part, the M/S manipulators from the opposite side of the power manipulator were able to assist freely. Since the degree of assistance of the M/S manipulators was improved (Table I), it was thought that working efficiency improved.

CONCLUSIONS

The dismantling activities, which consist of removal of the glove panel, dismantling of the interior equipment and dismantling of the GB body and made up about 45% of the dismantling of the GBMP in the GBDF, could be first performed by remote control. The working efficiency of remote operated dismantling work is approximately comparable to the efficiency of direct dismantling work. There are 30 percent fewer workers in the remote operated dismantling work than in the direct dismantling work, so a reduction in the cost of GB dismantling work by remote operation can be expected. Therefore, remote operated dismantling work will be able to perform safe and efficient GB dismantling.

REFERENCES

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