Status and Future Plan of Decommissioning of the Plutonium Fuel Fabrication Facility – 14089

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ABSTRACT

The Plutonium Fuel Fabrication Facility in the Plutonium Fuel Development Center of the Japan Atomic Energy Agency is now in its decommissioning phase. In the facility, stabilizing activities of nuclear materials that remain in the facility and dismantling activities of gloveboxes have been carried out simultaneously. Various technological developments for dismantling of gloveboxes to enhance workers' safety and cost effectiveness have been implemented.

INTRODUCTION

The Plutonium Fuel Fabrication Facility (PFFF) in the Plutonium Fuel Development Center of the Japan Atomic Energy Agency was constructed for the purpose of developing mixed oxide (MOX) fuel fabrication technology through manufacturing fuel for the experimental fast reactor JOYO and the advanced thermal reactor FUGEN. The PFFF started its operation in 1972. JOYO fuel manufacturing activities were switched to the Plutonium Fuel Production Facility in 1988, which was constructed to supply the fuel for JOYO and the proto-type fast breeder reactor MONJU. The FUGEN fuel fabrication in the PFFF was terminated in 2002 because the operation of FUGEN was ended in 2003.

The PFFF is now in its decommissioning phase. In the facility, the nuclear materials that remain have been fabricated into a stabilized form by utilizing materials for FUGEN fuel assembly that remain, and the gloveboxes have been dismantled simultaneously. Glovebox dismantling activities in the PFFF are performed manually by workers, each wearing an air-feed suit, with mechanical tools in a plastic enclosure which is constructed around the gloveboxes to prevent spread of contamination. This dismantling methodology is technically well-established and relatively easy to implement. However, the mental and physical loads placed on workers wearing the air-feed suits are intensively high. Therefore, workers' safely issues still exist and need to be resolved. Moreover, working times for the air-feed suited workers are restricted to only one hour per day, which in turn makes shortening of the schedule and cost savings almost impossible. R&D on new dismantling methods including utilization of heavy equipment suitable for workspaces in the PFFF with anti-contamination measures to strengthen the work performance in the plastic enclosures has been started to reduce the above mentioned potential risks and costs. Technological developments to enhance workers' safety by adopting robot arm technology and reduce secondary waste generation have also been carried out.

OUTLINE OF THE PFFF

The PFFF plant is a building of reinforced concrete construction with two stories above ground. Its architectural area is about 9,500 m^2. In the PFFF, two MOX fuel fabrication lines were installed : one for JOYO (referred to as the FBR line) and the other for FUGEN (the ATR line). The annual fabrication capacities of the FBR and ATR lines were 1 ton and 10 tons of MOX, respectively. The principal specifications and the cumulative production of the MOX fuel manufactured on each line are shown in table I.

TABLE I. The principal specifications and the cumulative production of MOX fuel manufactured in the PFFF

	FBR line	ATR line	
Fuel user	JOYO	DCA[a]	FUGEN
Pu enrichment	18%-30%	1%	2%
Total number of assemblies	375	3,952[b]	773
Pu used	1.0 tons	0.1 tons	1.8 tons
MOX fuel produced	5 tons	12 tons	139 tons
Period of production	1972-1988	1972-1988	1975-2001

[a] DCA : Deuterium Critical Assembly in the Oarai Research and Development Center of the Japan Atomic Energy Agency.
[b] Total numbers of fuel pins fabricated.

Standardized gloveboxes with 6x2.5x1m dimensions were adopted in both the FBR and ATR lines in order to minimize the initial construction cost. The gloveboxes have small transfer tunnel connections on two sides. The main part of the gloveboxes is made of 4-mm thick stainless steel except some gloveboxes in the wet recovery test process, which used 6-mm thick stainless steel, and the analytical laboratory, which used vinyl chloride resin. The number and capacity of the gloveboxes, open port boxes and hoods in the PFFF are shown in table II.

TABLE II. The number and capacity of the gloveboxes, open port boxes and hoods in the PFFF

Category	Number[a]	Capacity (m^3)[a]	Notes
FBR line	18	295.3	
ATR line	28	342.5	
Wet recovery test process	14 (10)	126.9 (90.4)	Nitric acid solution was handled
Waste liquid treatment	4	54.0	
Analytical laboratory	22	42.8	
Open port box	7	15.2	Contamination level is low.
Hood	7	10.6	Contamination level is low.
Total	100 (10)	887.3 (90.4)	

[a] The number and capacity of gloveboxes, open port boxes and hoods are those before the decommissioning phase was begun. The numerical values in parenthesis are the number and capacity which have already been dismantled.

BASIC DECOMMISSIONING PLAN

Establishment of the basic decommissioning plan of the PFFF was started after the FUGEN fuel fabrication was ended. About 10 tons of nuclear materials that remain in the PFFF at that time. First of all, it was necessary to consider how the nuclear materials should be removed from the PFFF. Moreover, a storage space needed to be reserved for the waste generated during dismantling of gloveboxes. After a thorough examination, the following schedule was planned in which the activities (1) to (3) should be implemented in advance and the activities of (4) would be the final tasks. [1]

(1) Treatment of nuclear materials that remain (2009 - around 2020)
Nuclear materials that remain are fabricated into a stabilized form by utilizing materials for FUGEN fuel assembly that remain. These assemblies are stored for some period.

(2) Dismantlement of gloveboxes (2010-around 2030)
Gloveboxes are dismantled according to the plan with priority on a risk of losing the containment of nuclear materials from the gloveboxes. Technological developments to enhance worker safety and cost effectiveness are implemented, and the technology is deployed properly.

(3) Storage of generated wastes (2011-around 2035)
Nonflammable radioactive solid wastes generated from dismantling activities are stored in the freed-up spaces obtained after glovebox removal. The wastes will be carried out to a new waste treatment facility which has been under review for construction.

(4) Final survey and demolition of the building (around 2035 and after)
The exhaust system is removed after the nuclear materials that remain and

nonflammable radioactive solid wastes are removed. The final facility survey of the building is performed, and then the license for the radiologically controlled area is terminated and building is demolished.

STABILIZING TREATMENT OF NUCLEAR MATERIALS THAT REMAIN

At the time of terminating fuel fabrication in the PFFF, there were about 10 tons of nuclear materials that remained. Most of their plutonium-uranium ratios had been adjusted to the specifications of FUGEN fuel. In order to execute the facility decommissioning program, it is indispensable to remove all the nuclear materials that remain in the gloveboxes and the nuclear material storage area. It was decided to fabricate into a stabilized form by utilizing materials for FUGEN fuel assembly that remain because of the following reasons.

a) *Safety*: Long-term storage is possible in a stable and a safe manner because the nuclear materials are made into a pellet form, and a welding seal is applied after loading into a cladding tube.
b) *Safeguards*: Rationalized inspection is possible because the total number of items in terms of material accountancy is reduced from 3,000 to 100 or less.
c) *Cost*: Additional investment is kept low because the existing fuel fabrication line and the components of the fuel pins and assemblies that remain can be used effectively.
d) *Storage efficiency*: Storage of concentrated nuclear materials is possible because the density of a pellet is about 5 times larger than the bulk density of MOX powder. The existing assembly storage space can be used effectively.
e) *Handling*: Assemblies can be handled without any difficulty, because existing shipment containers for FUGEN assemblies are available.
f) *Reprocessing*: PuO_2 which is slightly soluble in nitric acid can be dissolved without any residual matter by fabricating plutonium and uranium into a solid solution by a sintering process. Recovered plutonium can be used as MOX fuel effectively in the future.

After the stabilizing treatment plan of the nuclear materials that remain was determined, the procedure for changing the license on the PFFF was carried out. The stabilizing treatment was begun in 2009 after examination of pelletizing technologies. About 20% of the treatment of nuclear materials that remain have been accomplished. If everything goes well, the stabilizing treatment will be finished around 2020.

EXPERIENCES IN GLOVEBOX DISMANTLEMENT IN THE PFFF

About $90m^3$ of the gloveboxes have been dismantled in the PFFF thus far, and the progress ratio is about 10%. Those gloveboxes used in handling nitric acid solutions have been undergoing dismantling since 2010 as the first priority group, because they were considered to have the highest risk of losing the containment of nuclear materials from among the gloveboxes in the PFFF.

Glovebox dismantling activities are performed manually by workers wearing air-feed suits with mechanical tools in a plastic enclosure which is constructed around the gloveboxes for preventing spread of contamination. The basic steps to dismantle gloveboxes are summarized as follows. [2]

Step 1: Non-essential external equipment is removed.
Step 2: Interior glovebox surfaces and equipment are dusted off and wiped down. Spray fixative is applied to the contaminated surfaces of the equipment and the glovebox in order to decrease the level of airborne contamination in the plastic enclosure.
Step 3: The glovebox exhaust is disconnected from the ventilation system and the glovebox is isolated.
Step 4: Scaffolding to allow work at high places and plastic enclosure tents to control the spread of contamination are set up.
Step 5: The glovebox and heavy equipment are size-reduced and segregated into appropriate waste streams for packaging.
Step 6: The plastic enclosure tent is decontaminated and removed.

A schematic figure and photographs of the dismantling work are shown in figure 1.
The plastic enclosure tent is composed of a dismantling chamber, two-sets of contamination control rooms for workers to put on and take off their air-feed suits, and the final contamination control room for workers after taking off the air-feed suits.
The dismantling chamber is composed of two layers of tents and an exhaust system, which consists of a blower and two steps of HEPA filters, with 20-60 Pa in gage pressure negative to the surrounding room pressure. Also it should be mentioned here that the floor and walls of the dismantling chamber are covered with nonflammable sheets to protect from fire that may occur during size reduction. [3]

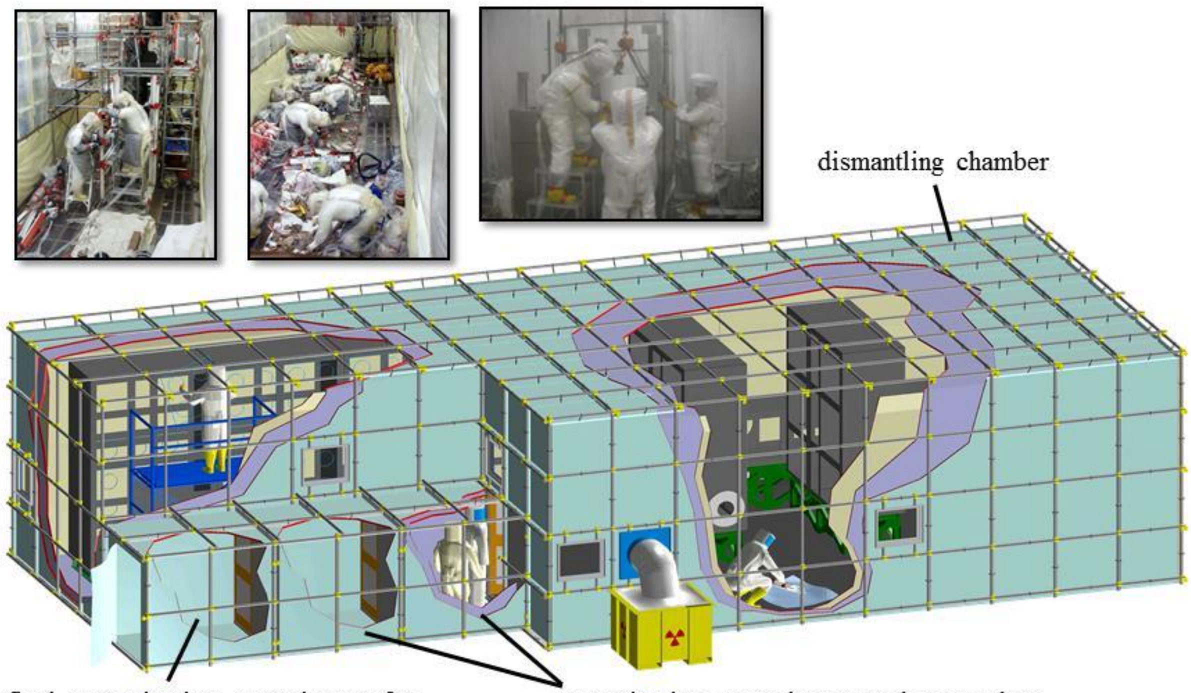

Fig.1. Glovebox dismantling activities conducted by workers wearing air-feed suets

As of December 2013, the glovebox dismantling activities have been carried out in two terms. About $43m^3$ and $47m^3$ of gloveboxes were dismantled in the 1st and 2nd terms, respectively. The former dismantling period took about 8 months, while the latter took about 12 months. The percentages of each dismantling step to the total work labor are shown in table III. The workforce needed in step 5 occupied the largest portion of the total workforce and these values were about 50% - 60% of the total works. Shortening the period of this step is very important in order to reduce the cost of dismantling activities.

TABLE III. The ratio of each dismantling step to the total workforce ($43m^3$ and $47m^3$ are the volumes of the gloveboxes that were dismantled during the two terms)

Step	1st term ($43m^3$)	2nd term ($47m^3$)
Step 1	5%	6%
Step 2	4%	4%
Step 3	7%	7%
Step 4	17%	15%
Step 5	50%	57%
Step 6	17%	11%

Wastes generated from dismantling activities are shown in table IV. The resulting amount of wastes was about 1.2 - 1.3 times larger than the capacity of the dismantled gloveboxes themselves. The reason for this increment is due to the generation of the secondary wastes such as the plastic enclosure tents and air-feed suit related items, in addition to the primary wastes. It is important to reduce the amount of wastes generated in order to reduce the final disposal cost. Therefore, it is necessary to continue development for technologies to reduce waste generation.

TABLE IV. Waste generated from dismantling activities (43m^3 and 47m^3 are the volumes of the gloveboxes that were dismantled during the two terms)

		1st term (43m^3)	2nd term (47m^3)
Primary Waste	Flammable chlorinated wastes	1m^3	3m^3
	Other flammable wastes	4m^3	4m^3
	Non- flammable wastes	32m^3	29m^3
	Subtotal	37m^3	36m^3
Secondary Waste	Flammable chlorinated wastes	3m^3	5m^3
	Other flammable wastes	8m^3	11m^3
	Non- flammable wastes	5m^3	8m^3
	Subtotal	16m^3	24m^3
Total		53m^3	60m^3

R&D OF DECOMMISSIONING TECHNOLOGY

R&D of Remote Size Reduction Technology

Dismantling methodology is technically well-established and relatively easy to implement. However, there still exist drawbacks originating from the features of the air-feed suits, for instance, bulky inflated suits, layers of gloves and the limited size of the eyepiece on the headgear restrict the workers' ability and mobility and increase potential hazards.

Additionally workers need to use various types of sharp tools and handle large amounts of size-reduced metal objects having sharp edges and rough surfaces. Therefore, the mental and physical loads on workers are intensively high. And actual working times for each worker are restricted to only one hour per day, which in turn makes shortening of the schedule and cost savings almost impossible. To enhance workers' safety and cost effectiveness, technological development of remote size reduction with a robot arm system has been implemented.

When the robot arm system in the environment contaminated with plutonium needs repair or maintenance, workers wearing air-feed suits need to enter the contaminated workspace and fix the system. However, even to make a small repair, the possibility of fixing the system is considered to be very low because the flexibility of the suit is extremely limited. It is therefore very important to develop a durable robot arm system before putting it into practical use.

It was assumed that the joint parts of the robot arm were weak since a reaction force was applied repeatedly to it during cutting work in glovebox dismantling. Therefore, a mechanical bumper was set between the robot arm and the cutting tool, and cutting test was carried out using a test bed. It was confirmed that steel could be cut by a hydraulic cutter but with only a little impact to the joint parts of robot arm. Moreover, it was confirmed that the cutting work was faster than without the mechanical bumper. Also, the operator did not need to get additional skills, because the robot arm was able to access the cutting target smoothly owing to the buffering function of the bumper. The size reduction test image and photograph with the robot arm are shown in figure 2.

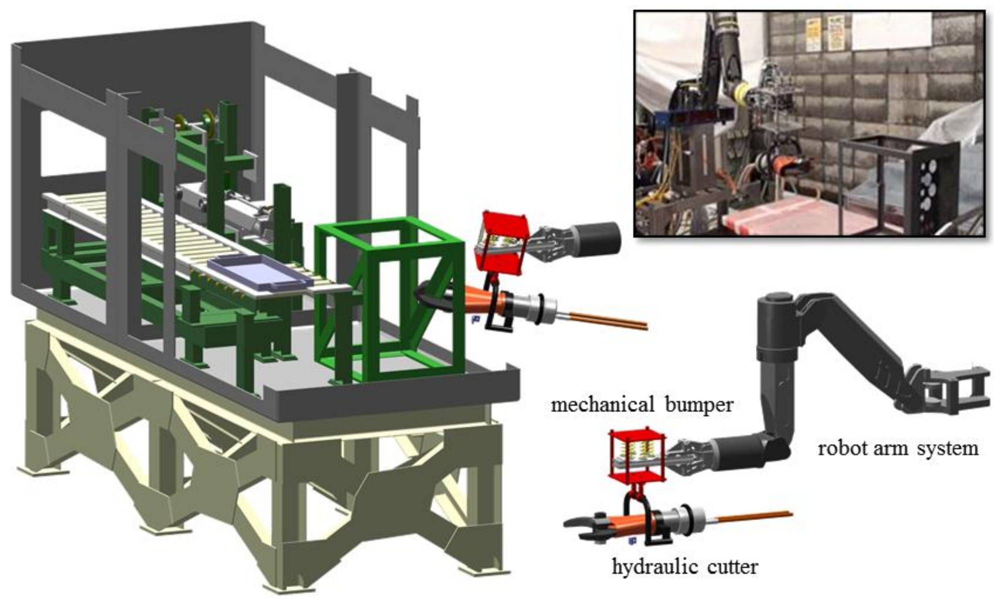

Fig.2. Size reduction test image and photograph showing the robot arm

R&D of Direct Filling Type Waste Drum System

Generated non-flammable waste is wrapped up using plastic sheets and tape in order to make it less hazardous to handle; this is because the waste usually has sharp edges and rough surfaces. The volume of secondary waste such as plastic sheets and tape has

reached about 30% - 40% of the total volume of waste generated. In order to reduce waste and increase ease of waste handling, the direct filling type waste drum system that can treat the waste without wrapping has been developed. The drum was designed to be used repeatedly.
This system adopts a double-layered cover as shown in figure 3. One cover is on the waste drum and the other cover is set at the bottom of the waste handling space to allow waste to be moved in and out. During the waste handling activities, the outsides of the two covers are press-fitted together with a gasket to prevent contamination, and the double-layered cover is held open for waste packaging. After putting waste into the drum, the double-layered cover is closed, and then the two covers are separated.

The confirmation test of direct filling type waste drum system was carried out during the 2nd term glovebox dismantling activities as a comprehensive test. It was found that the more times the test was repeated, the more the contamination level of the gasket went up. And decontamination load of workers was very high after several usages. As measures to mitigate this, it would be effective to raise the manufacturing accuracy and harden the gasket. But these modifications are technically difficult in reality. Restriction in the number of repeatable uses may resolve this problem.

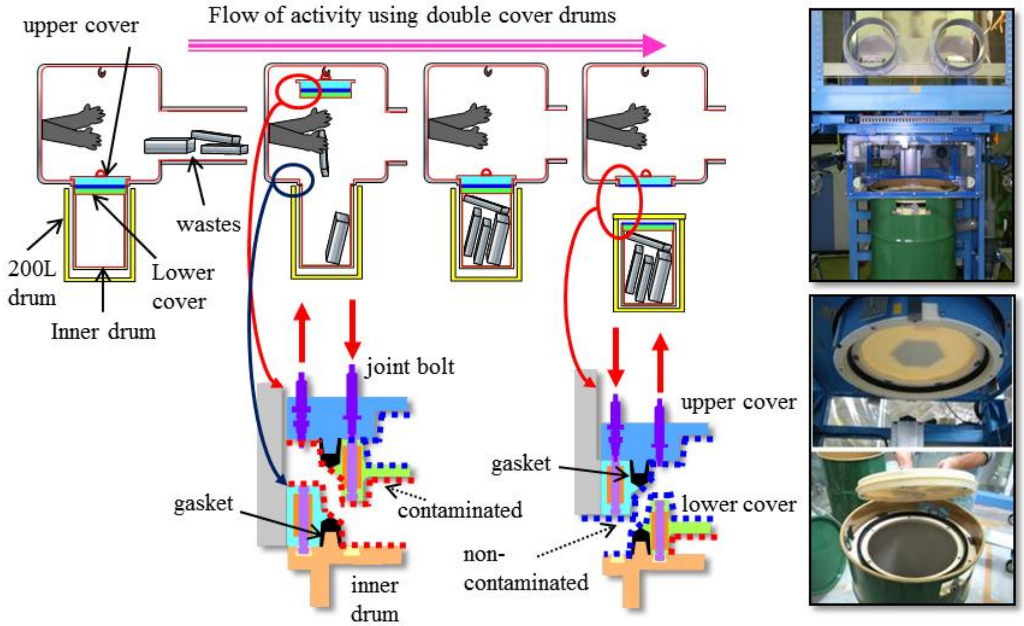

Fig.3. Direct filling type waste drum system

R&D ON NEW DISMANTLING METHODS INCLUDING APPLICATION OF HEAVY EQUIPMENT

It is necessary to perform glovebox dismantling activities in a safe, fast and cost effective manner. For that purpose, it is important to reduce the amount of work that must be done while wearing an air-feed suit. R&D regarding new dismantling methods that could substitute hands-on work with more remotely done work has been started. The concepts of new dismantling methods, named as “Smart Decommissioning System”, are summarized as follows.

1) Application of remote controlled heavy equipment with an anti-contamination measure provided by a plastic enclosure.
2) Minimization of the work that must be done while wearing an air-feed suit.
3) Maximization of the operating time in the plastic enclosure by applying heavy equipment.
4) Reduction of the amount of secondary wastes by promoting the reuse of heavy equipment, tools, etc. for dismantling.
5) Reduction of R&D costs by promoting new applications of presently available commercial equipment.

Basic steps of the Smart Decommissioning System are summarized as follows.

Step 1: Construct a large and rigid plastic enclosure to keep the containment of contamination when moving the heavy equipment.
Step 2: Remove flammable materials to avoid fire that may occur during size reduction by the workers wearing air-feed suits.
Step 3: Divide a glovebox into two vertical sections to be able to access in with an arm of the heavy equipment.
Step 4: Remotely cut glovebox materials roughly by using heavy equipment with a gripper and heavy equipment with a cutting tool after taking the measures to prevent against flying cut fragments.
Step 5: Remotely transfer the cut materials to a size reduction and separation workspace in the plastic enclosure by a cart.
Step 6: Carry out size reduction, separation, wrapping and bringing out of the material as manual work with gloves.
Step 7: Reuse the heavy equipment, carts, etc. in the next dismantling task.

A schematic figure of the Smart Decommissioning System is shown in figure 4.

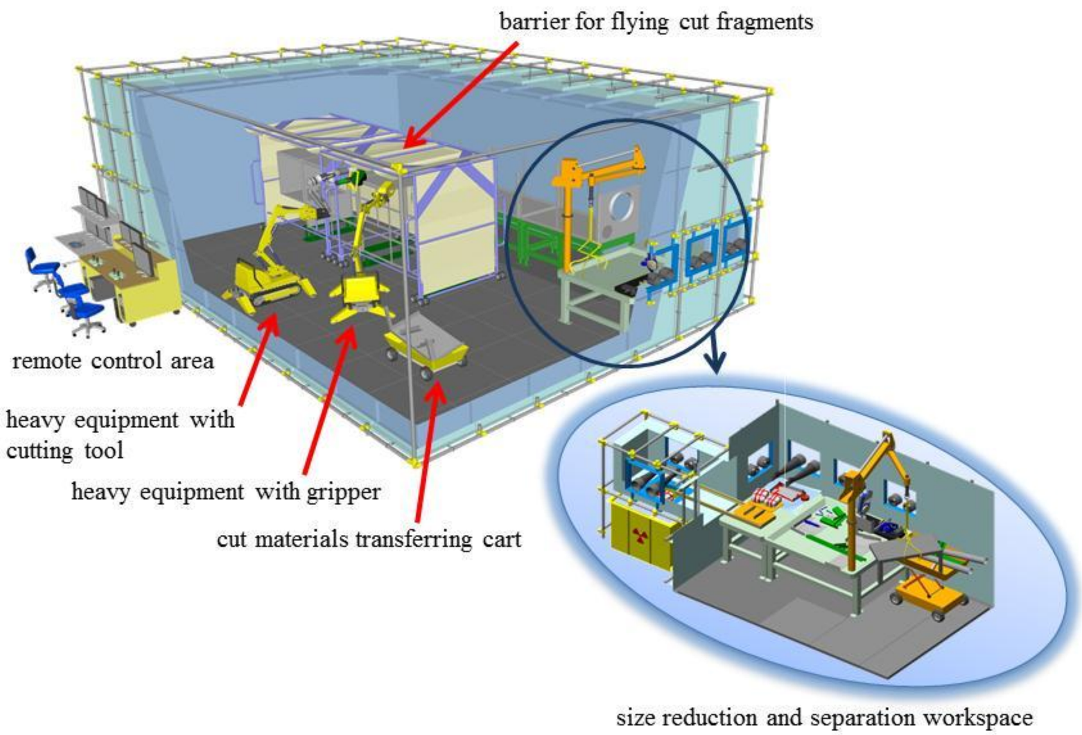

Fig.4. Schematic showing the Smart Decommissioning System

It is expected to apply that the knowhow acquired with the mechanical bumper can be used for the attachment of heavy equipment. And it is also expected the concept of the direct filling type waste drum system can be applied to containers for the reuse of heavy equipment, carts, etc.
The conceptual examination of the Smart Decommissioning System has been implemented. In the present plan, system design and mock-up examinations will be performed from fiscal year 2014 to fiscal year 2016, then, full-scale dismantling by the new methods will be performed in the PFFF. Each final development goal for reductions of time and cost of glovebox dismantling has been set as a 50% decrease in comparison with the conventional methods. For small rooms in the PFFF, the conventional methods still need to be applied for glovebox dismantling because the heavy equipment needs a large space. The other gloveboxes will be dismantled by the new methods. It is planned to finish dismantling of all the gloveboxes by around 2030.

CONCLUSION

The Plutonium Fuel Fabrication Facility in the Plutonium Fuel Development Center of the Japan Atomic Energy Agency is now in its decommissioning phase. Stabilization activities of nuclear materials that remain in the facility and gloveboxes dismantling activities have been carried out simultaneously. The progress ratio of the former is about 20% and the latter is about 10%.
It is necessary to perform glovebox dismantling activities in a safe, fast and cost effective

manner. For that purpose, R&D regarding new dismantling methods, named as “Smart Decommissioning System”, that could replace hands-on type work with more remote type work has been started. The new methods will be developed in the next three years. Full-scale dismantling by the new methods will be started from fiscal year 2017 in the present plan. When the new methods are deployed, it is expected they will significantly enhance worker safety and cost effectiveness.

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