Re-assembling Procedure of the Fuel Assemblies for the Nuclear Power Ship "Mutsu"

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Abstract. Japan's first voyage utilized by nuclear power was made by the nuclear powered ship "Mutsu" in 1990. After a research voyage in 1992, decommissioning work of the nuclear reactor for "Mutsu" was started to change it from the nuclear power ship to an ordinary power ship. Thirty-four irradiated fuel assemblies of "Mutsu" were removed from the reactor and transported to the Reactor Fuel Examination Facility (RFEF) in Nuclear Science Research Institute (NSRI) of Japan Atomic Energy Agency (JAEA). "Mutsu" fuel assemblies were loaded into a hot cell of RFEF using the roof-gate as the top loading procedure. After the reliability confirmation tests, fuel assemblies were re-assembled for reprocessing. To perform the reliability confirmation tests and re-assembling, new devices were developed and installed in the hot cells, "Fuel assembly transportation device" for transporting the fuel assemblies between the hot cells, "Upper nozzle cutting device" for removing the upper nozzle from the fuel assembly, "Fuel rod drawing device" for drawing a fuel rod from the fuel assembly and so on. Thirty-four fuel assemblies were re-assembled as six PWR type fuel assemblies in order to adjust the acceptable specifications of the reprocessing plant in JAEA: the shape of fuel assembly is the same as the PWR type commercial reactor fuel and the average enrichment of uranium in the assembly is under 4.0%. This paper reports the re-assembling techniques of the "Mutsu" irradiated fuel assemblies for reprocessing.

1. INTRODUCTION

The "Mutsu" was built as the first nuclear power ship in Japan. However, the minor leak of neutrons and gamma rays from the reactor pressure vessel occurred during the first stage of the power raising test in the Pacific Ocean. The research voyage of about 82000 km was made after the repairs of shielding [1]. The decontamination program for "Mutsu" was started in 1992 after completing the nuclear power ship project. In the decontamination work, the "Mutsu" fuel assemblies were re-assembled like power plant fuel assemblies for the reprocessing of the fuel. The re-assembling work required for the fuel handling in the reprocessing plant was performed at the Reactor Fuel Examination Facility (RFEF) in Nuclear Science Research Institute (NSRI) of Japan Atomic Energy Agency (JAEA). "Mutsu" fuels were stored in the custom-designed casks and transported three turns for thirty-four fuel assemblies by ship from Aomori prefecture to RFEF in Tokai village. Additionally, the handling device and in-cell transportation device were developed in RFEF for re-assembling work. The re-assembling of these fuels was performed in 2001–2007 and the re-assembled fuels were stored in the storage pool in RFEF. After decontamination, the "Mutsu" was rebuilt from the nuclear power ship to an ordinary power ship "Mirai".

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2. SPECIFICATIONS OF “MUTSU” FUEL ASSEMBLY

A marine nuclear reactor was developed in Japan. The reactor type was pressurized-water reactor (PWR) with 36 MW in thermal power. Two types of fuel assemblies having the different fuel enrichment, namely A-type: 3.24% and B-type: 4.44%, were loaded in “Mutsu” reactor. The cladding tube was made of stain-less steel. The specifications of “Mutsu” fuel assembly are shown in Table 2.1.

TABLE 2.1. SPECIFICATIONS OF “MUTSU” FUEL ASSEMBLY

Total amount of assemblies	34
Total amount of rods	3808
^{235}U enrichment [%]	3.24 and 4.44
UO_2 [kg]	87
Length of assembly [mm]	1,431(L) × 167.7(W) × 167.7(W)
Alignment of rods	11 × 11
Total weight [kg]	Approx. 123

3. DEVELOPMENT OF RE-ASSEMBLING DEVICES

To perform the re-assembling work, the new devices were developed and installed in the hot cells. Details of specifications of these devices are described below.

3.1. In-cell transportation device

The aim of the device was to receive the loaded assembly and transport it between hot cells. The assembly was loaded into the cell through a roof-gate and transported to the adjacent cell. The device is composed of a receiving basket for holding the assembly and a carrier unit for transportation of the assembly with basket to the adjacent cell, as shown in Fig. 3.1. The carrier unit can be moved by electric power when the other routines are performed in the cell. The carrier moving rollers and frames are made of stain-less steel. The assembly can be transported safely and smoothly by this device.

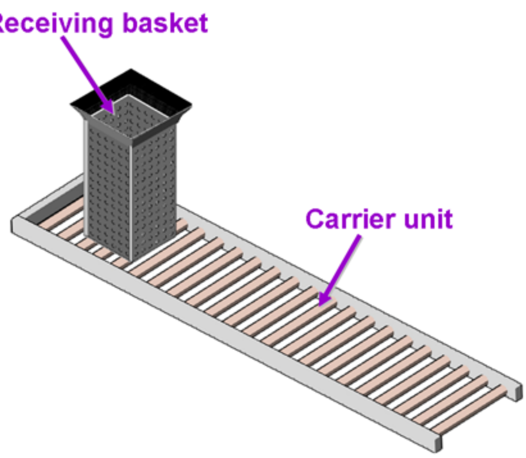

FIG. 3.1. A schematic drawing of the in-cell transportation device.

3.2. The cutting device for upper nozzle

For first step of re-assembling procedure, the upper nozzle was unfixed from the assembly for drawing the fuel rods. The skeleton components of the fuel assembly such as the upper and lower nozzles and spacer grids were welded on the side plate of the fuel assembly. Therefore, the upper nozzle had to be cut away from the side plate. However, the space between the upper nozzle and top of the fuel rods was only 7 mm in distance, which required adjusting the cutting position adequately to avoid doing damage to the fuel rods. The cutting device consists of a cutter head with a driving unit and a chucking device for the fuel assembly. A portable band saw was selected for the cutter head. A schematic drawing of the cutting device is shown in Fig. 3.2.

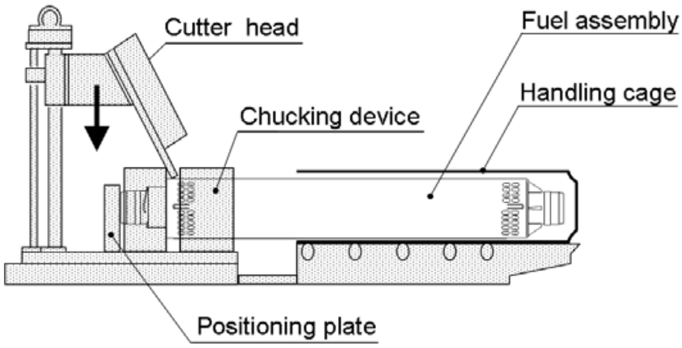

FIG. 3.2. A schematic drawing of the cutting device.

The fuel assembly, which was placed in the handling cage, was laid on the table of the cutting device. The cutting position was adjusted by bringing the top of upper nozzle into contact with the positioning plate which was set on the cutting device. These procedures can make the accurately cutting, because the fuel assemblies were manufactured with high dimensional accuracy. Then, the fuel assembly was clamped by the chucking device. The upper nozzle was cut with the cutter head moving down.

After the cutting, the fuel assembly with handling cage was raised up and moved by in-cell crane. Therefore, the upper nozzle could be cut from the fuel assembly quickly and accurately by the cutting device.

3.3. Fuel rod drawing device

A collet chuck system was adopted for conventional drawing device, which could not be inserted between the side plate and fuel rod at the outermost row. The side plate was an obstacle to draw the fuel rod by using the conventional device. Additionally, the conventional drawing device required a manipulator operation to move the chucking device, which would spend a lot of time during the process. Consequently, the drawing device was improved for “Mutsu” fuel rod. The drawing device has a compact clamping head with compression air actuation unit. A schematic drawing of the drawing device is shown in Fig. 3.3.

The clamping head has a ring shaped rubber, a compression tube and a spring. The compression tube moves up against the spring force to release the compressive force to the rubber when the compressed air is injected into the clamping head. Without the injection of the air, the spring in the clamping head would compress the rubber to clamp the top of fuel rod by the friction force of over 300 N. To select the rubber compression system, diameter of clamping head had to be smaller than the conventional drawing device. The improved clamping head can be inserted in the gap between side plate and outer side of fuel rods of the “Mutsu” fuel assembly. The operation of this device, chuck opening and closing, was controlled from operation area using air valve. Furthermore, fuel rod clamping condition was indicated by indicator rod attached in the clumping head.

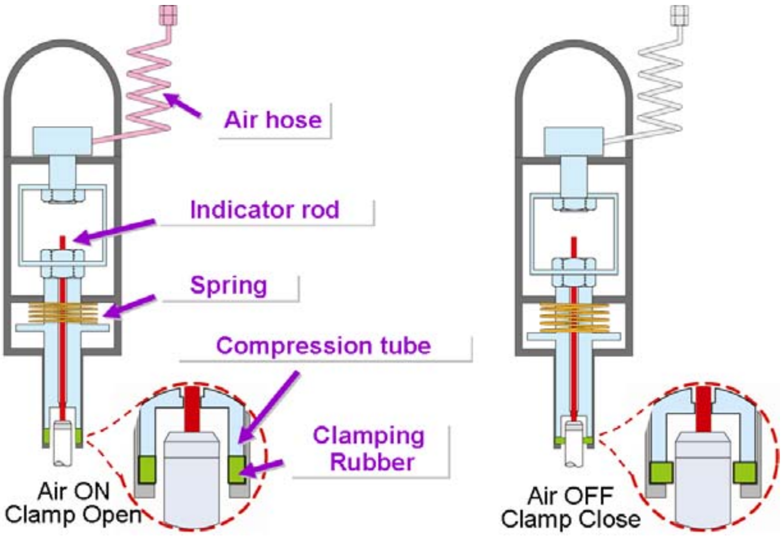

FIG. 3.3. A schematic drawing of the drawing device.

4. PROCEDURE OF RE-ASSEMBLING

Approximately Six assemblies of “Mutsu” fuel were re-assembled to one PWR type-like assembly for reprocessing. The surface cleaning of the “Mutsu” assemblies using an ultrasonic water bath and the external observation test of the assemblies were performed as the first process of re-assembling work, and then cutting of the upper nozzle, drawing of the fuel rods, the visual inspection of the fuel rods and re-assembling process were preformed in series. Detailed procedures of each process are described below.

4.1. Upper nozzle cutting

The upper nozzle was cut by the cutting device with the cutting accuracy of ±1mm. There was no additional damage of the fuel rod in this procedure.

4.2. Fuel rod drawing

The fuel rods were drawn from the fuel assembly using the in-cell crane and the fuel rod drawing device. In this procedure, deformation of the fuel rod was confirmed to measure the pull-out force by a load cell unit which is attached between the in-cell crane and the drawing device. The fuel rods drawn from the assemblies were placed in the temporary storage rack by each assembly.

4.3. Visual inspection of fuel rods

After the drawing of all fuel rods, the confirmation test was performed by the periscope in the cell to search the defect at the surface of the fuel rods and deformation during irradiation.

4.4. Fuel rods insertion and assembling

The length of “Mutsu” fuel rod was approximately one third of the commercial reactor fuel rod (1123 mm as Mutsu, approx. 3900 mm as commercial reactor). Therefore, three rods of “Mutsu” fuel were inserted in the same grid cell of the PWR type skeleton vertically as three-tiers. To improve the efficiency of the insertion, twenty-four rods were inserted in the thimble tube because the re-assembling fuel will not be loaded in a reactor. However, it was necessary to adjust the average enrichment of a fuel assembly less than 4.0% for the acceptable specifications of the reprocessing plant. The “Mutsu” fuel assembly was comprised of two enrichment types of fuel rods; A-type is 3.24% and B-type is 4.44%. The identifying mark of the enrichment, namely “A” or “B”, was carved at the bottom side of fuel rods. In order to adjust the average enrichment of re-assembled fuel assembly to less than 4.0%, arrangements of the insertion position for the fuel rods were needed. The fuel rods were inserted into the PWR skeleton in accordance with the predetermined arrangement pattern. The typical arrangement pattern is shown in Fig. 4.1. To insert the fuel rod adequately to the arrangement pattern, the identifying mark of enrichment (A or B) was confirmed using check sheets in every insertion process. After that, portal films of insertion patterns were taken to confirm the inserted fuel rods. Finally, thirty-four fuel assemblies were re-assembled as six PWR type-like fuel assemblies in order to adjust the acceptable specifications of the reprocessing plant. The photograph of re-assembled assembly is shown in Fig. 4.2.

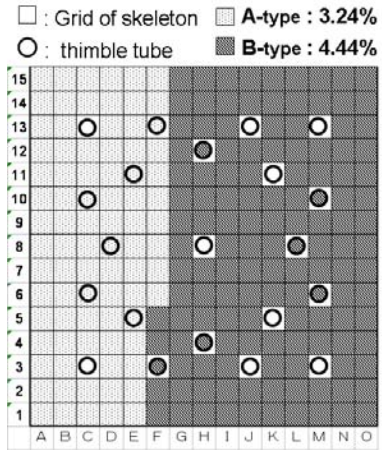

FIG. 4.1. The typical arrangement pattern of fuel rods.

FIG. 4.2. Re-assembled PWR type fuel assembly.

5. SUMMARY

The new devices and systems were developed in RFEF to perform the reprocessing work of “Mutsu” fuel, and re-assembling work for 34 “Mutsu” fuel assemblies was performed in 2007.

The re-assembled fuels will be transported to the reprocessing plant in JAEA, near future.

6. ACKNOWLEDGMENT

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Posters ***(maybe different title)***