Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2007
October 21-26, 2007, Miami, Florida, USA

EXPERIENCE ON RETURN SHIPMENTS OF RESEARCH REACTOR SPENT NUCLEAR FUELS IN JAEA-TOKAI

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ABSTRACT
Research Reactor Spent Nuclear Fuel (RRSNF) has successfully been transported from Japan to the United States 16 times since the foreign Research Reactor Spent Nuclear Fuel Acceptance Policy began in 1996. Of these, the Japan Atomic Energy Agency (JAEA) has carried out shipments to the US nine times, totaling 1,463 fuel elements. Several types of spent fuels generated from three research reactors (JRR-2, JRR-3 and JRR-4) have been transported from the JAEA- Tokai site.

For transportation, the operator must comply with many kinds of procedures and inspections. It takes about one year to complete a shipment, including preparation works and following necessary procedures. The preparation works include evaluation of the radioactivity, cutting off the fuel nozzle and handle for fuel element, weighing each element, decontamination of the cask, etc. Additionally, there is an obligation to explain the details of the spent fuel transportation to various organizations such as local governments and fishermen's unions.

In 2004, the deadline for receiving RRSNF by the US was extended to May, 2019. At the JAEA-Tokai, the JRC-80Y-20T shipping cask was modified in 2006 in accordance with changes following a new design approach.

This modification was made for the lid of the cask to mitigate impact forces under a hypothetical accident scenario. In addition, new safety analyses and designs were based on “Regulations for the Safe Transport of Radioactive Materials 1996 Edition (as amended 2003) Safety Requirement No.TS-RS-R-1” by IAEA.

We will continue safe RRSNF transportation using best practices in compliance with the international nuclear non-proliferation policy, and in consideration of applicable regulations. This paper describes the practices and procedures of JAEA-Tokai concerning RRSNF transportation.

INTRODUCTION
The government of the US started receipt and management of foreign Research Reactor Spent Nuclear Fuel (RRSNF) in the US in 1996 subsequent to completion by the DOE of an

Environmental Impact Statement. The subject of receipt was a US-origin spent fuel which was taken out from a reactor core by May, 2006 and which should arrive at the US by May, 2009 considering cooling period and shipment arrangement for three years. In addition, the receipt time limit was extended until May, 2019 in November, 2004.
JAEA concluded the contract of receipt with DOE in 1997 and the first shipment of the spent fuel from the JAEA-Tokai began from next year. As of the end of April, 2007, JAEA-Tokai carried out eight times shipment to the Savannah River Site (SRS)..

1. OUTLINE OF RRSNF

The spent fuels which completed transportation was generated from three research reactors (JRR-2, JRR-3 and JRR-4) on the Tokai site by 532 in all. Those spent fuels are generally said, "MTR type", and it is composed of a lot of fuel plates.
JRR-2 was constructed as the first multi-purpose research reactor (10MW) in Japan based on CP-5 of Argonne National Laboratory, but it has been closed-down in 1996.
JRR-3 was the first Japanese designed and constructed reactor (10MW) and it was modified in 1990 as a high-performance, multi-purpose research reactor with a maximum output of 20MW. To distinguish the reactor after it modified, it is called "JRR-3M."
JRR-4 was constructed to test the reactor shielding of the first Japanese nuclear ship "Mutsu" and it was also modified in 1996 as a multi-purpose research reactor with a medical irradiation facility.
Figure 1. shows the transported main RRSNF. Table 1. shows the kind of transported RRSNF.

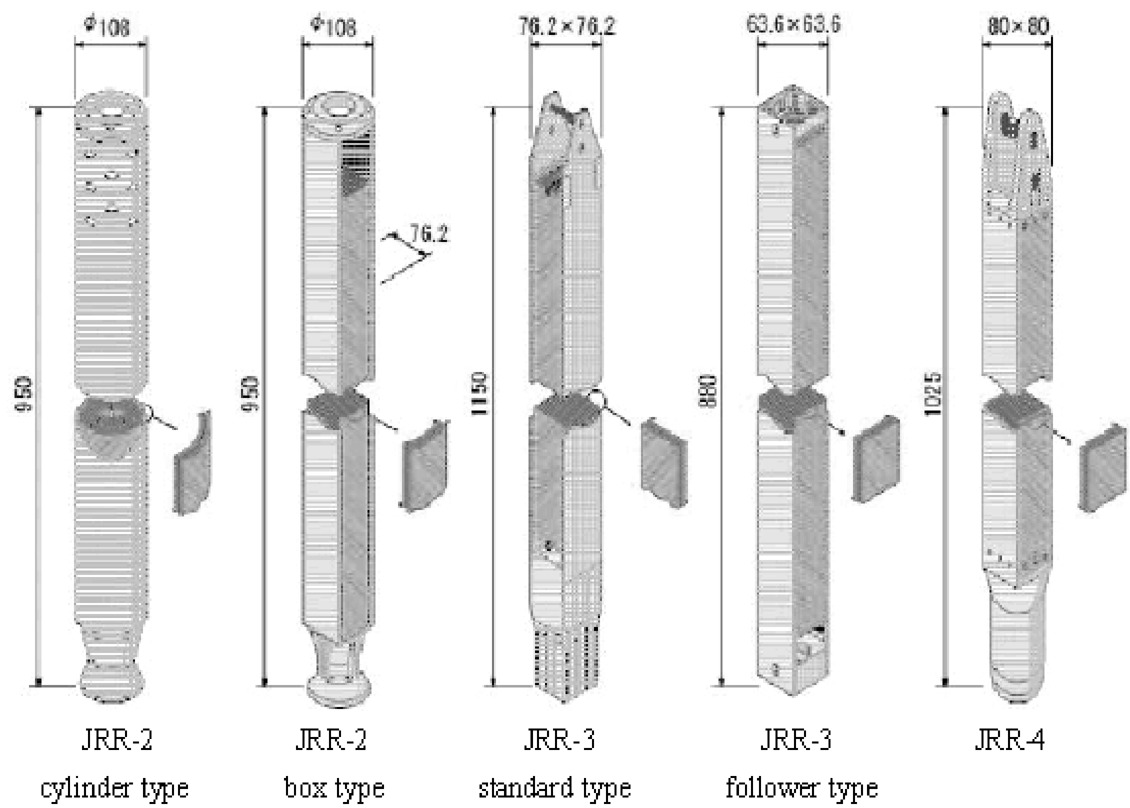

Figure 1. Transported main RRSNF

Table 1. Kind of transported RRSNF

Times	Years	Reactor	Type	Enrichment (Initial) (%)	Burnup (Average) (%)	Amount	
						Subtotal	Total
1	1998	JRR-2	Cylinder	93	31.9	28	60
			Cylinder	45	29.8	32	
2	1999	JRR-2	Cylinder	45	36.9	60	60
3	2000	JRR-2	Cylinder	45	22.1	52	52
4	2001	JRR-2	Box	93	30.5	6	80
		JRR-3	Standard	20	20.3	30	
		JRR-4	Box	93	16.5	43	
		JRR-4	Box	20	17.8	1	
5	2002	JRR-3	Standard	20	34.3	80	80
6	2003	JRR-3	Standard	20	46.9	80	80
7	2004	JRR-3	Standard	20	33.2	80	80
8	2007	JRR-3	Follower	20	28.4	40	40

1.1 Spent fuel of JRR-2

In JRR-2, LEU fuel of 20% enrichment was used at first and HEU fuel of 93.3% enrichment was used for the performance improvement. In addition, the HEU fuel of 45% enrichment, named MEU (Middle Enrichment Uranium) fuel conveniently to distinguish from the 90～93% enriched fuel, was used from 1986 to closed-down.

The HEU fuel of JRR-2 was a uranium-aluminum alloy, and the box and cylinder types. On the other hand, the MEU fuel was a uranium aluminum dispersion type (aluminide fuel) and cylinder type. The average burn-ups of the HEU spent fuel and the MEU spent fuel is about 32%(FIFA) and 30%(FIFA), respectively.

All of the JRR-2 spent fuels have been already transported to the SRS by 2001.

1.2 Spent fuel of JRR-3M

In JRR-3M, LEU aluminide fuel with enrichment less than 20% was used until 1999 and then it has been converted to a silicide fuel. The reactor core is composed of the standard type fuels and the follower type fuels which moves together with the control rod.

The average burn-ups of the aluminide spent fuel which has been transported so far is about 36% in a standard type, and about 28% in the follower type..

1.3 Spent fuel of JRR-4

In JRR-4, HEU fuel of 93% enrichment was used until 1996 and LEU fuel which enrichment is less than 20% has been using since 1998.

The average burn-ups of the HEU spent fuel and the LEU spent fuels are about 17% and 18%, respectively.

2. OUTLINE OF PACKAGING

The JAEA constructed two stainless steel Packaging, JRC-80Y-20T, for reprocess of spent nuclear fuels of research reactors and had utilized them for transportation since 1981.

This Packaging is cylindrical, which consists of the body (shell and body bottom plate) and lid. In the size, it is about 1.9m in diameter, about 2.1m in height, and weight is about 23tons.

The main body is fabricated by forged stainless steel, and its inner diameter, shell thickness and base plate thickness are 82cm, 31cm and 30.5cm, respectively. The lid is also made from stainless steel with a thickness of 37cm and fastened to the main body by 16 bolts. In Packaging, there is a basket which maintains the fuels.
Also, the lid is provided with the vent valve for air-drain, and the bottom portion of the body is provided with the drain valve for water-drain, and the portions of the lid and the body connection are sealed with the double O-ring made of silicon rubber.
In order to absorb the drop impact and dissipate the decay heat, the top and bottom portions of the packaging are provided with the fins fixed by welding.
For the purpose of subcritical control of the package, the sintered plate of Boron-Carbide and Aluminum are installed to the basket as a neutron poison.
This Packaging was used to transport the spent fuel four times until 1988 when the reprocessing plant was closed. However, because we maintained the Packaging afterwards, and were acquiring the license continuously, transportation to DOE was able to be started at once.
In 2003, we carried out an additional analysis to add the silicide fuel to the "Contents of Package". An additional analysis used impact analyses code LS-DYNA, which was safety analysis which had been often used in recent years.
It was recognized that plastic deformations (0.1mm) could be seen in the seal region of the package under the hypothetical accident conditions in the results of safety analysis.
We considered several kinds of modification in the analyses, then we finally found that if the lid was modified, any other plastic deformation could be seen. The modification of the lid began in 2005, and completed including all the examinations by 2006.
Figure 2. shows externals of both the original and the modified Packaging.

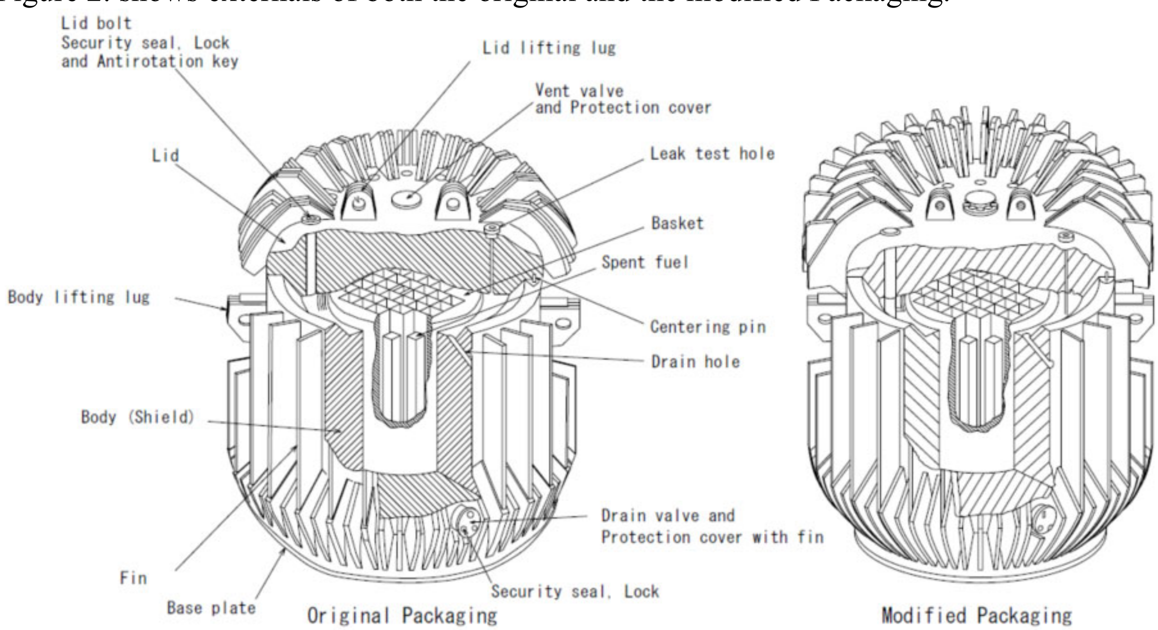

Figure 2. Externals of the original and the modified Packaging

The outline of the modification of Packaging is described as follows.

1) The surface of seal area of lid is to be flat.
2) Thirty two long fins have a chamfer of 20 mm × 20 mm.
3) Sixty eight fins are welded as additional fins.
4) Lid lifting lugs have a chamfer of 20 mm × 20 mm.
5) Lid has a chamfer of 17mm × 2mm around inside below corner.
6) Two short fins at 0 degree and 180 degree are sliced.

Figure 3. shows modification points of the Packaging.
The safety of the Packaging concerning modification was strictly examined by Ministry of Education, Culture, Sports, Science and Technology (MEXT), and Approval of package Designs was issued.

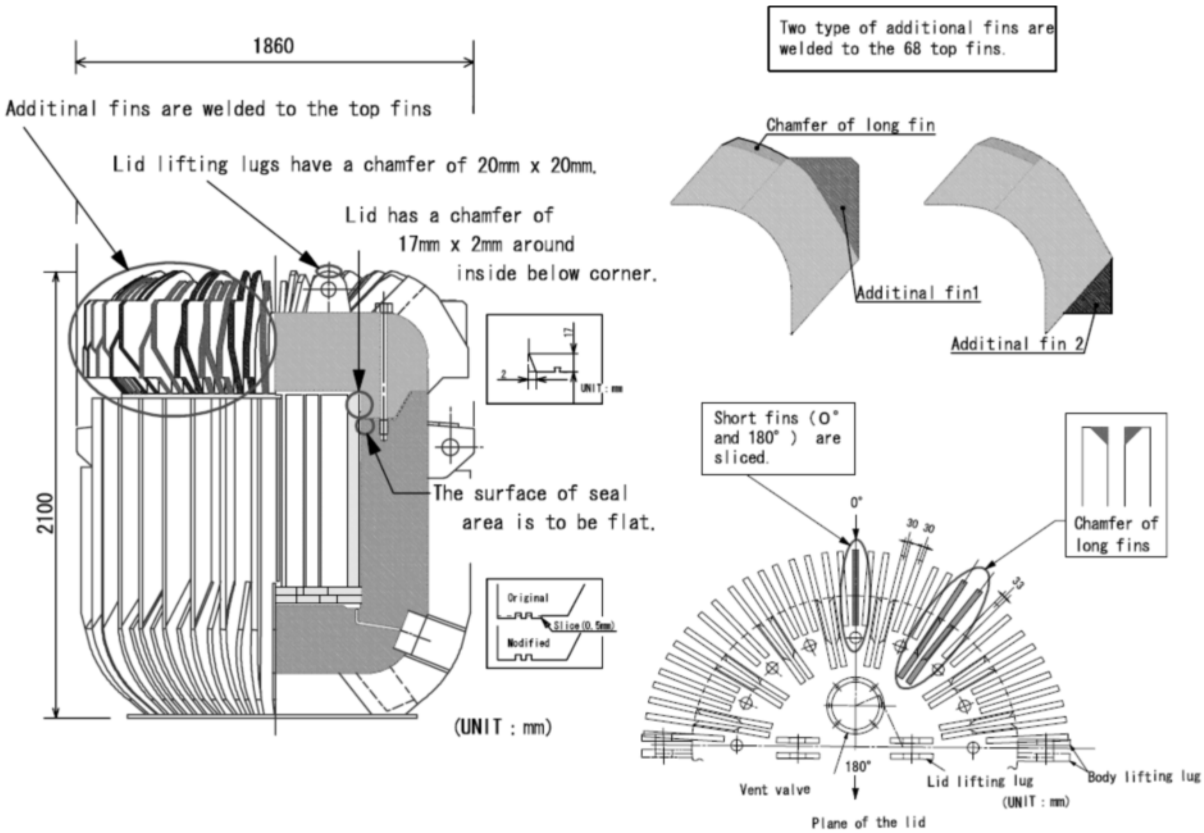

Figure 3. Modification points of the Packaging

3. OUTLINE OF RRSNF TRANSPORTATION

3.1 Preparation prior to transportation

The spent fuel to be transported was chosen, and the specifications of the kind, number, concentration, radioactivity, produced plutonium, and the operation log, etc. are confirmed in the beginning. These specifications are submitted to the USDOE in order to obtain the Approval of the USDOE.
The radioactivity of spent fuels is calculated by the ORIGEN code and the produced Pu is also calculated by the SRAC code. In addition, the criticality analysis and the shielding analysis of the spent fuels for transportation are done because of the safety confirmation.

3.2 Construction of package (Loading of spent fuels)

Figure 4. shows the flow of the spent fuel of JRR-3.
The spent fuel taken out of the reactor core moves to No.1 spent fuel storage pool after it cools for one year or more in the pool near the reactor core. The spent fuel to be shipped is moved from No.1 spent fuel storage pool to No.2 spent fuel storage pool. When the JRR-4 spent fuel is shipped, it is moved to No.2 spent fuel storage pool in JRR-3.
Top and bottom parts of a fuel element are cut off by using the cutting machine with a disk cutter to reduce fragments except nuclear materials as much as possible and the weight is measured for every cut fuel element.

Prior to loading of spent fuels, the periodical self-inspections such as a visual test, an air tight test and so on are carried out to confirm the soundness of a Packaging.
Then the Packaging is sunk into the fuel storage pool with the depth of about 6m. The water in the pool is controlled with an ion exchange resin so that the conductivity of water is less than 10 μS/cm, and that the pH of water is the range of 5.0 to 7.5.
A neutron source of americium-beryllium (Am-Be) is inserted into the fuel basket and neutron measurement is carried out to confirm subcriticality whenever each fuel element is loaded to the Packaging. The loading is carried out with a handling tool by manual operation. After loading all spent fuels, the lid is closed in water and the Packaging is taken out from the storage pool and the decontamination is carried out for the surface of the Packaging. The water in the Packaging is extracted a little through the drain line to measure radioactive nuclides. The integrity of the loaded RRSNF is confirmed by measuring the radioactive nuclide of the sampled water, and water in the Packaging is drained afterwards.
Before the package (packaging and radioactive contents) is installed in the tie down device, it is checked by MEXT whether the package is constructed in accordance with approved package design, whether the radioactive contents are within acceptable limits of approved package design, and whether the dose rate on the surface of the package, surface contamination, containment system, etc. satisfy the approved technical standards. Whenever the package is shipped, inspections shown in Table 2 are carried out and it is confirmed that the package is suitable to the standard.
After the inspections, the package is installed in the tie down device.

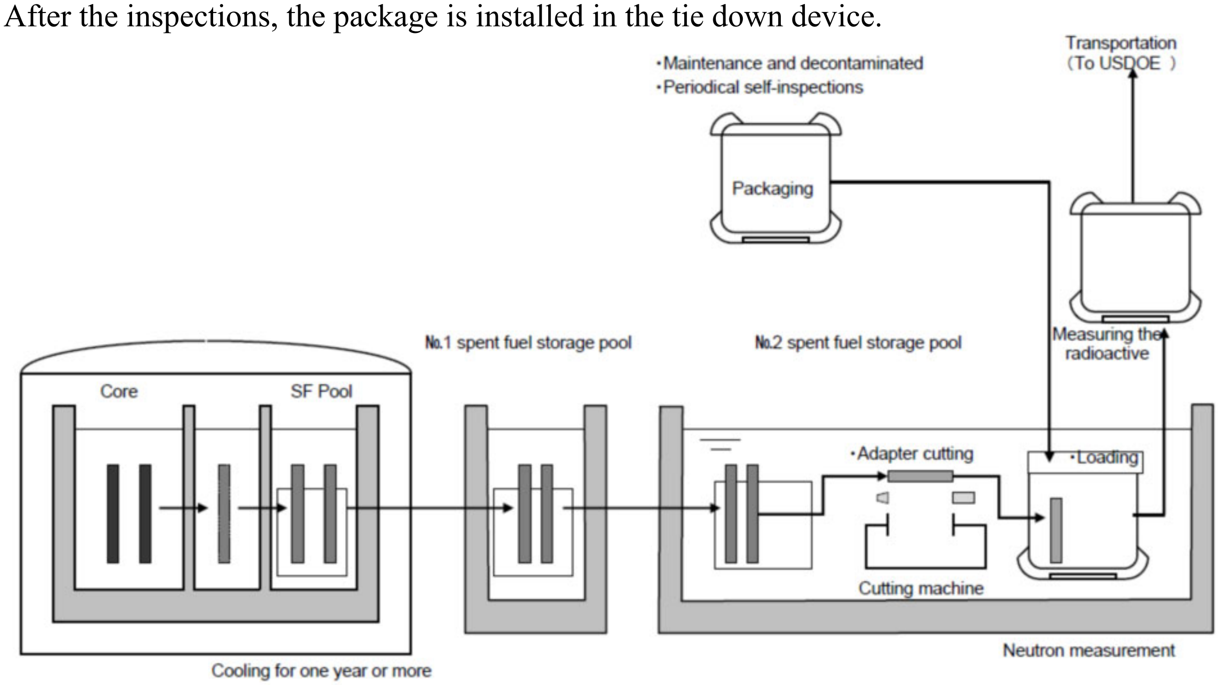

Figure 4. Flow of the spent fuel of JRR-3

Table 2. Prior to shipping inspection points

Inspection item	Inspection method	Successful standard
1. Visual inspection	Inspect visually outside appearance of package on condition that the fuel element is loaded.	To have no such unusualness as harmful flaw, crack, and shape, etc.
2. Lifting inspection	Inspect visually after lifting up, which shall be done when visual inspection is carried out for inspection of packaging.	To have no unusual deformation on lifting device of packaging.
3. Weight Measurement inspection	Confirm according to calculation, etc.	To be $23.2 \cdot 10^3$ kg or less.
4. Surface contamination measurement inspection	Measure surface radiation level of package with smear method.	To be ; α : 0.4 Bq/cm^2 or less β, γ : 4 Bq/cm^2 or less
5 .Radiation dose rate measurement inspection	Measure γ ray dose equivalent ratio and neutron dose equivalent ratio on condition that the fuel element is loaded.	To be 2 mSv/hr or less on surface and 100 ∝Sv/hr or less at a point 1 m away from surface.
6. Subcriticality inspection	Inspect visually outside appearance of basket.	To have no harmful deformation and damage.
7. Contents inspection	1) Inspect visually loaded conditions. 2) Confirm records relating to radioactive level, burning degree, calorific value, number of days of cooling, etc.	1) To be no existence of anything unusual on outside appearance. 2) To satisfy values described in SAR for vehicle transportation confirmation.
8. Surface temperature measurement inspection	Measure temperature of surface of package before transport, after the fuel element is loaded.	To be 85°C or less.
9. Leakage rate measurement inspection	Carry out pressurize test with compressed N_2 gas at above 4.2 MPaG, and inspect quantity of pressure drop.	Quantity of pressure drop shall be 0.00608 MPa or less per hour.
10. Package Internal Pressure Measurement inspection	Confirm to be opened in the air.	To be opened in the air.

3.3 Transportation

After loading the package on the trailer, the loading methods and dose rates around the trailer are checked in conformity with the technical standards by the Ministry of Land, Infrastructure and Transport (MLIT).

The package is transported by land to the port in the nuclear plant which is adjacent to JAEA-Tokai by the trailer. Experts for nuclear material control and radiation control are to accompany and necessary equipments such as radiation detectors, an extinguisher, etc. are also carried together.

The land transportation starts after confirming the condition (waves, winds and the swell of the ocean) is suitable for loading to the ship.

After the package is loaded from the trailer to the ship, the loading methods and dose rates around the ship are checked again by MLIT.

The package was transported to the available port of the US by way of the UK at the beginning and then it was conveyed to the SRS by land. However, the package is transported directly to the port in the US in recent years, because of the viewpoint of the physical protection.

4. RETURN OF CASK

he cask taken out RRSNF is decontaminated in the SRS and returned to Japan. Although the cask is sufficiently decontaminated, it is treated as a radioactive material. Therefore, it is returned to Japan with a limited ship which can convey a radioactive material.

CONCLUSIONS

RRSNF transportation to the US is being carried out, spending about one year including preparation works in accordance with the legislation and paying attention carefully to the safety. So far, 532 RRSNFs was transported to the US successfully.

The transportation of RRSNF needs a lot of cost. Though the future is forecast that it runs up the fuel cost and the cost for the physical protection measures, we make an endeavor for the acquisition of budget, and will continue RRSNF transportation safely considering the legislations as well as making the best use of former experiences.

ACKNOWLEDGMENTS

We wish to express our gratitude to the people who cooperated in the transportation of RRSNF and the modification of the Packaging etc., and will hope for a lot of advices and cooperation in the future.

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