Two-tier packing of spent nuclear fuel into transportation containers

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The concept of two-tier packing of spent nuclear fuel in transportation and packing containers appeared a long time ago. When designing the TK-18 containers, VNIPIET envisaged the possibility of a more compact spent nuclear fuel packing by removing suspensions, and considered it in engineering analyses of containers. OKBM, too, considered the possibility of more compact packing during development of fuel assemblies.

Two-tier packing seems attractive from the viewpoint of large volumes of spent nuclear fuel transportation and possible long-term storage (to 10 years) of spent fuel in containers prior to transportation. Compact packing can reduce transportation costs and the required quantity of containers. Compact packing can be achieved in any type of containers: TK-18, TUK-108-1 or TUK-120.
What is the essence of two-tier packing? Fuel assemblies of propulsion reactors consist of the fuel part and the hollow suspension, which treated as radioactive waste. Any transportation container is high enough to accommodate two fuel parts stacked on top of each other. Therefore, fuel parts of spent fuel assemblies can be cut off from their suspensions and packed into transportation containers in two tiers.

Suspensions are put into specially designed containers for radioactive waste storage and later disposed of.

Cutting of spent fuel assemblies into parts can be performed in a special “hot” chamber designed by OKBM, and includes three operations:

- separation of suspension from the fuel part;
- removal of burrs on the cuts;
- installation of a mushroom shaped end cap, identical to the suspension top part.

The “hot” chamber is a thick-walled metallic box (see Fig. 1). One of the four walls has a round opening where the cutting device is arranged. The other walls, the cover, and the bottom accommodate fuel assembly fixing devices, a lamp, a television camera, a chip collection filter, an air vent with an aerosol filter, a washing and decontamination system, and a capsule for collection of accidentally spilled solid radioactive waste. After washing of solid wastes that form during spent fuel assembly cutting, the deactivating liquid goes through the chip collection filter to the main liquid radioactive waste collection system.

Figure 1. Cutting chamber

The cutting chamber is delivered with a set of special devices and tools that ensure effective performance of required operations and require minimum attendance. The entire process of cutting takes about 30-40 minutes; consequently, if work is organized in two shifts, it is possible to cut 4500-6000 spent fuel assemblies per year.

Radiation exposure dose during treatment of a KLT-40 spent fuel assembly with maximum heat rating, after 5 years of decay storage after reactor shutdown, is given in Table 1. The collective dose amounts to 4.17 man-μSv, which corresponds to 12.6 man-mSv per year maximum. The maximum individual dose is 3.2 mSv per year, i.e. 16% of the allowable limit established in radiological safety code NRB-99 (20 mSv). If we consider spent fuel assemblies of reactor cores with lower power release and longer decay storage after reactor shutdown (such as the spent fuel from nuclear submarines stored in the Andreeva and Sysoeva Bays, or spent fuel unloaded directly from the decommissioned submarines), personnel exposure doses will be 2-10 times lower.

TABLE 1 – PERSONNEL RADIATION DOSES DURING CUTTING OF ONE SPENT FUEL ASSEMBLY IN THE CUTTING CHAMBER (5-YEAR DECAY STORAGE AFTER REACTOR SHUTDOWN)

OPERATION	**PERSONNEL WORK PLACE**	***LABOR*** **MAN-MIN (MAN-HOUR)**	***Dose rate at the work place,*** **µSv/h**	**Personnel radiation dose, man·µSv**
1. Installation of refueling container	Work platform No.1	5 (0.083) 5 (0.083)	0.2 1	0.017 0.083
2. Spent fuel assembly fastening	Work platform No.2	5 (0.083)	3	0.25
3. Spent fuel assembly cutting	Work platform No.2	5 (0.083)	3	0.25
4. Observation of spent fuel assembly cutting via television camera	Work platform No.2	5 (0.083)	10	0.85
5. Transportation of the top part of spent fuel assembly into the transportation container	Work platform No.1 No.2	5 (0.083) 5 (0.083)	1 3	0.083 0.25
6. Removal of burrs	Work platform No.1	9 (0.15) 1 (0.017)	1 50*)	0.15 0.85
7. Installation of end caps	Work platform No.1	9 (0.15) 1 (0.017)	1 50*)	0.15 0.85
8. Observation of spent fuel assemblies via television system	Work platform No.2	3 (0.05)	1	0.05
9. Other additional activities	Work platform No.1 No.2	5 (0.083) 5 (0.083)	1 3	0.083 0.25
Total		**68(1.14)**	**-**	**~4.17**

*) For 0.5 m from the opening in the protective plate of the upper chamber of the spent fuel assembly cutting container

Since 2003, the storages of “Lotta” recharging ship have been using the cutting chamber (see the photo) designed and patented by OKBM (RF Patent No.2240611). This chamber has been used to cut more than 900 of spent fuel assemblies with non-processable uranium-zirconium fuel. This type of spent fuel occupies the largest part of the storage because its processing will not be possible during the next 8-10 years. This fuel is withdrawn from “Lotta” storage and transported to building 5 of RTP “Atomflot”. Two-tier packing allows to reduce the number of required TK-120 transportation containers by 45 pieces; thus, expenses for containers manufacturing are reduced by €9.0 million.

Successful operation of the cutting chamber at “Lotta” allows us to recommend the same two-tier packing option for transportation of spent nuclear fuel from the shore-based SevRAO and DalRAO storages (the Andreeva Bay and the Sysoeva Bay) to the reprocessing facility.

Let us consider the spent nuclear fuel storage in the Sysoeva Bay. The total number of spent fuel assemblies in that storage is several thousand pieces. Twelve train runs will be needed for their transportation. One train run costs 21.0 million rubles (€600 thousand). If we use two-tier packing, the number of train runs is reduced to 6, so 126 million rubles (€3.6 million) will be saved in transportation.

These estimations were made only for the Susoeva Bay. If we also consider the spent nuclear fuel, which is about to be unloaded from nuclear submarines, and several thousand spent fuel assemblies currently stored in the facilities of DVZ “Zvezda”, total reduction of fuel transportation costs for the Pacific Region can amount to 230 million rubles (€6.5 million).

The cost of cutting chamber fabrication is 23-25 million rubles; the cost of establishing appropriate supporting infrastructure is estimated at 27-33 million rubles. Estimations were made by OKBM and DVZ “Zvezda” in 2005; with account of escalation, total costs as of today can amount to ~ 70 million rubles (€2 million). Current expenses for additional process operations, personnel training and wages are estimated at ~ 5 million rubles (€140 thousand).

The feasible term for manufacturing the chamber and installing the supporting infrastructure is 1 year and 3 months starting from the funding date.

The optimal siting choice for the cutting chamber is the railroad yard in the Konyushkovo Bay. Here it is possible to establish the cutting facility for the spent nuclear fuel transported from the Sysoeva Bay by the PM 74 recharging ship, and for spent fuel assemblies that are to be transported from DVZ “Zvezda” by a pontoon, which is currently under construction.

The additional operation of fuel assembly cutting into two parts will not bring any significant changes in the entire transportation and process schedule. This operation can be performed uninterruptedly for the spent fuel assemblies stored at the Konyushkovo Station, awaiting the train. We believe that there will be no technological difficulties. Preparation of one container with two-tier stacking of fuel parts takes from 2 to 3.5 days if the personnel works in two shifts. Consequently, make up of one train will take 40-42 days maximum. With the train frequency of one every two months, all preparations will fit well into the train schedule.

For this meeting of the Contact Experts Group, the economic effect from the use of the two-tier packing option for the spent nuclear fuel in the Andreeva Bay was not estimated. In our opinion, given the total amount of spent nuclear fuel stored there and the transportation and process schedule currently under development, establishment of a spent fuel assembly cutting facility will noticeably reduce transportation costs and the required number of transportation containers.

Storage of radioactive waste produced as a result of spent fuel assembly cutting will not pose any difficulties. Containers with the cut-off suspensions will be stored either in three-compartment nuclear submarine units in accordance with the accepted rules and codes, or in the newly established regional solid nuclear waste depositaries. Total activity of all suspensions from one reactor core loading, with the maximum power release, will equal $3 \cdot 10^{12}$ Bq and 5.1 10^{11} Bq respectively 10 and 20 years after reactor shutdown.

Issues related with removing the lower-tier fuel assemblies from the transportation container were discussed with the specialists of PO “Mayak”. In accordance with the bilateral protocol, if it is decided to use two-tier packing, OKBM will develop the corresponding technology and tooling as per the input data from PO “Mayak”.