# Handling of Spent Nuclear Fuel from Atomic Submarines at Mayak PA

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## 1. Introduction

FSUE MAYAK PA is a modern large-scale nuclear facility, which activities include among others the transport and reprocessing of spent nuclear fuel of so called Vessel Transport Facilities (VTF), i.e. atomic submarines and surface ships.

Transport and reprocessing of spent nuclear fuel from nuclear submarine reactors from North and Pacific marines was initiated in 70s last century, when an intermediate storage in RT-1 Mayak PA was put in operation.

For above 35 years of operation near 250 hauls have been carried out to transport spent fuel from marine bases, above 160 ton of spent fuel was reprocessed.

## 2. Transport of spent nuclear fuel from atomic submarines

The transport route distance between Mayak PA and North marine bases is 3,000 km and 7,500 km to Pacific ones.

Beginning from 1994 submarine spent fuel has been transported in transport containers TUK-18 (TUK-108/1) that comply with national and international safety regulations in terms of type B packages under routine operation and incidents. Radiation and nuclear safety in the course of spent fuel transport is ensured by transport container structural elements.

Following logistical measures are performed at the Mayak PA radiochemical plant and within the Ministry of Communications system to ensure safe railway transport of spent fuel from nuclear submarines:

- certified packages and special railway cars TK-VG-18, TK-VG-18A, TK-VG-18-2 are used for transport;
- transport is arranged according to guidelines concerning special freight transport using travel warrant train as transport category;
- freight is escorted by a specially trained and qualified team of Mayak PA radiochemical plant personnel;
- special trains are provided with guard and physical protection of freight;
- transport is monitored;
- before dispatch of the special train Mayak PA informs supervisory authorities on the scheduled transport;
- quality assurance system is functioning at the radiochemical plant concerning nuclear material transport accomplishment;
- there is a rescue team functioning at Mayak PA with necessary hardware.

Special service of Mayak PA and guards of RF Ministry of Home Affairs arrange activities for nuclear material physical protection.

### 3. Mayak PA potentials for reprocessing of nuclear submarine spent fuel

Mayak PA reprocesses only those spent fuel assemblies of the entire range, which comply with the branch standard (OST). The most significant requirements of the standard determining the acceptability and reprocess ability of spent fuel assemblies at Mayak PA are the following ones:

- structural integrity of spent fuel assembly;
- tightness in terms of fuel;
- free retrievable fuel assembly from transport canister;
- fuel composition fits the Process Manual for spent nuclear fuel reprocessing.

One more mandatory requirement for spent fuel assembly acceptance at Mayak PA is the availability of data on weight parameters of nuclear materials in assemblies. If no assembly manufacturer data are available, weight parameters of nuclear materials are assigned according to the regulation “Special Conditions of Conditioned Spent Fuel Assembly Delivery from Affiliate No.2 of FSUE “SevRAO”.

Spent fuel assemblies, which comply with the branch standard, are called *conditioned* ones.

Spent fuel assemblies, which could not be reprocessed for any reasons, are not accepted at the facility. Two types are distinguished among such assemblies: *non-reprocessable* and *non-standard* ones. Spent fuel assemblies, the fuel composition of which does not fit the Process Manual, belong to non-reprocessable ones (U-Zr, U-Be, for example). Spent fuel assemblies belong to non-standard ones, if their technical state does not allow reprocessing them under routine process conditions. They are called *defective* assemblies as well.

All non-standard spent fuel assemblies could be grouped in following way on base of transport and handling mode at Mayak PA:

***First group*** (relative conditioned spent fuel assemblies)

These assemblies

- do not have mechanical failures of structure (breaks, fractures, bending etc.);
- are leakproof in terms of fuel, confirmed with appearance or water analysis (if any) in storage cell;
- are free (by gravity) retrievable of and loadable in the canister cell.

Spent fuel assemblies of the first group comply with the branch standard in terms of main parameters and could be transported for routine reprocessing at Mayak PA. Deviations from the standard could concern the state of the transport canister and assembly passport data.

If the transport canister does not meet the requirements of the standard OST (made of structural steel, for example), the assembly has to be re-loaded into a canister made of stainless steel (X18H10T).

In case of corresponding document execution an occasional transport of spent fuel assemblies is admissible in storage canisters of type 22M, 24M with defective plug latching mechanism and broken bottom membrane.

***Second group*** (not damaged untight spent fuel assemblies)

These assemblies

- do not have mechanical failures of structure (breaks, fractures, bending etc.);
- are free (by gravity) retrievable of and loadable in the canister cell;
- are untight in terms of fuel (without spilling of fuel).

Spent fuel assemblies of the second group are to be re-loaded into faultless tight canisters before forwarding for reprocessing. Such kind of assemblies should be prepared for reprocessing at Mayak PA according to a technology, which excludes the contamination of the intermediate storage water (for example, removing the plugs from the canisters not in the storage pond, but in a cell where assemblies are prepared for cutting; this process will require manufacturing of special tools for manipulator). Re-loading of spent fuel assemblies from one canister in another could be replaced by inserting of the untight canister in an extra designed for such case tight can.

***Third group*** (destroyed spent fuel assemblies)

These assemblies

- have mechanical failures of structure up to lack of the gripper part and/or blank ends, but surely with the active part;
- could be untight in terms of fuel;
- are free retrievable of the canister cell (not jammed).

Spent fuel assemblies of the third group should be loaded into tight cans before forwarding to reprocessing. Can structure should allow handling them with routine equipment (canisters, grips, tools etc.), applied at Mayak PA.

***Fourth group*** (non-retrievable spent fuel assemblies)

These assemblies

- are not retrievable from the transport canister with help of normal and additional force (are jammed);
- could have any damages (surely with at least a portion of the active part);
- could be untight in terms of fuel.

To reprocess spent fuel assemblies of the fourth group either the storage canister should be cut in single tubes, or assemblies should be retrieved from the storage canisters and re-loaded into untight cans for drying (if necessary) and transferring into cutting cell. To perform the above mentioned operations (including collection of spilled spent fuel and solid radioactive waste handling) special unit should be constructed at Mayak PA equipped with respective techniques and accessories.

In this case non-retrievable spent fuel assemblies could be transported to Mayak PA in storage canisters of type 22M, 24M or in subassemblies of the type 6 containers loaded in an extra designed for such case tight can (similar to canisters of the second group of spent fuel assemblies).

Spent fuel assemblies of lower group number could be transported and reprocessed according to the scheme, accepted for spent fuel assemblies of higher group number.

**If it is impossible to assess the technical state of spent fuel assemblies, they should be delivered and prepared for reprocessing according to the fourth group handling procedure.**

Conditioned spent fuel assemblies are reprocessed according to the current flow chart, which includes:

- transport of spent fuel assemblies to Mayak PA;
- loading of spent fuel assemblies into intermediate storage pond;
- operations arrangement;
- mechanical cutting (grinding) of spent fuel assemblies;
- dissolution of irradiated fuel;
- clarification and extraction of solutions.

Spent fuel assembly reprocessing according the above mentioned flow chart results in target product extraction: purified uranium, plutonium and neptunium.

Radioactive wastes are generated in the course of spent nuclear fuel radiochemical reprocessing. There are liquid, solid and gaseous wastes according to their aggregate state.

Current system of liquid and solid waste handling at the RT-1 plant includes following steps:

- liquid radioactive waste: collection, intermediate storage in storage tanks, conditioning (fractionation, evaporation), solidification, long-term storage.
- solid radioactive waste: collection, sorting, conditioning, packing, intermediate storage, transport, disposal;
- gaseous radioactive waste: radioactive aerosol trapping and off-gas purification up to reference levels of atmospheric discharges of impurities.

Radioactive wastes are divided in three categories according their activity levels: low-level waste (LLW), medium-level waste (MLW) and high-level waste (HLW).

*High-level wastes (HLW)* (organic and aqueous) are stored in special storage tanks. A storage tank represents a concrete cave lined with stainless steel 12X18H10T. Each tank possesses an independent cooling system consisted of coils submerged in solution. Air blowing of tanks is provided to prevent explosive gas mixture accumulation containing hydrogen and methane, which are generated as a result of radioactive aqueous solution radiolysis. Air enters through a special intake.

Safe HLW storage in tanks is ensured by

- solution cooling in the course of their acceptance and storage;
- radiolytic gas dilution up to explosion-proof concentrations;
- sampling of gaseous phase to determine hydrogen and methane content;
- sampling of stored solution;
- limiting of HLW beta activity.

Preventive scheduled measures are carried out according to respective regulations to ensure accident-free operation of storage tanks.

Solutions are periodically given out for evaporation.

Solidification (vitrification) process brings up the rear of the HLW handling chain, consisting in transforming of radionuclides and other environmentally dangerous compounds in solid bodies (glass-like materials) in electric furnaces of EP-500 type. Solidified HLW are disposed in a special facility for a long-term storage. In the course of solidified waste storage heat is being generated due to radionuclide decay. There is an air cooling system provided in the storage facility in form of free cavities, through which air is fed for can cooling.

Storage tank capacities at the RT-1 plant are 70% filled up.

*Liquid medium-level waste (MLW)* are evaporated and than solidified. It is admissible to fill in MLW solutions into storage tanks for intermediate storage. A portion of MLW solutions are discharged into a special industrial pond according

to annual discharge quota agreed with Federal Medical and Biological Agency (FMBA).

*Liquid low-level wastes (LLW)* are fed in a discharge reservoir of the special pumping facility. The special pumping facility is designed for liquid LLW collection from the plant and further periodical solution feeding to treatment facilities. After decontamination solutions are discharged into special industrial ponds.

Collection, categorization and sorting of *solid radioactive waste (SRW)* is performed just in the locations of its generation using special containers (depending of SRW category). There are specially equipped sites in the plant for SRW intermediate storage. SRW are removed from the shops with special transport vehicles. FMBA issues a sanitary-and-epidemiologic letter for every transport vehicle of the radiochemical plant designed for SRW transport.

Process SRW (end elements of spent fuel assemblies, metal structures of spent fuel assemblies and fuel element claddings) are disposed in permanent storages.

Non-process wastes are disposed depending on their category

- in permanent facilities (medium-, and high-level SRW);
- in a landfill in the former basin of a pond (medium-, and low-level SRW);
- in a quarry burial (low-level SRW).

Control inspection and preventive repair of structural elements and equipment of permanent storages for solid radioactive waste are performed according to the annually compiled schedule.

Observation of burial state and radiation monitoring on their territories is arranged according to the Radiation Safety Standards NRB-99 and OSPORB-99. If a beyond-limit deviation is revealed, measures will be developed for the facility under control to recover contamination and eliminate reasons of the environment contamination.

To reveal information necessary for the assessment of the safety of dormant ground SRW burials investigations are performed periodically to determine contamination level of soil-vegetable cover, surface air, atmospheric radioactive fall-out rate, radionuclide carry-over from burial with vegetable cover, radionuclide migration rate from SRW to surrounding ground.

*Gaseous radioactive waste* in form of gases and aerosols are subjected to multistage decontamination and purification up to admissible discharge levels.

All technological processes in the radiochemical plant RT-1 are arranged compiling with following requirements:

- not to exceed the admissible exposure limits to workers (personnel) and population due to normal operation, failures of normal operation including design accidents, as well as restriction of exposure due to beyond design accidents;
- not to exceed admissible limits of radioactive material discharges and releases, environmental content of radioactive materials;
- to prevent nuclear accidents;
- maximum possible recovery of nuclear accidents

Safe operation of the plant is ensured due to consecutive realization of multi-zone protection concept based on a system of physical barriers against distribution of ionizing radiation, nuclear materials and radioactive substances, as well as technical and administrative measure system for physical barrier protection and maintenance of their efficiency, and protection of workers (personnel), population and environment.

In particular, technical and administrative measures in nuclear-dangerous areas are directed

- to prevent spontaneous chain reaction both at normal conditions and in case of one foreseen initial event;
- to prevent uncontrolled and unauthorized reprocessing, accumulation, movement, transfer and transport of nuclear materials;
- to prevent break of nuclear safety terms and requirements regulated by process documentation and normative documents.

According to current regulations following documents are compiled by specialized institutions in case new equipment or facilities are put in operation:

- opinion letter concerning nuclear safety;
- environmental impact assessment,

confirming nuclear and environmental safety of new production.

## 4. Handling of LWR spent fuel assemblies in the framework of the Project "Gremikha"

Currently a significant amount of non-standard spent nuclear fuel has been accumulated in permanent and intermediate coastal storages of FSUE "SevRAO". To accept and to reprocess it technical preparations are necessary concerning transport, unloading, intermediate storage in the storage pond, spent fuel assembly pre-treatment for reprocessing and handling of generated solid radioactive waste.

Scope of necessary preparation depends on the character and grade of inconsistency of spent fuel assemblies with the branch standard.

In early 2009 first shipment of conditioned LLW spent fuel assemblies was carried out from the Chervyanaya Bay (Gremikha) to Mayak PA. Second shipment of conditioned LLW spent fuel assemblies is scheduled for September 2009.

To arrange the acceptance of non-standard spent fuel assemblies from the Chervyanaya Bay at Mayak PA (according to defect types there are spent fuel assemblies of the third and the fourth group) it is necessary to arrange an *assembly pre-treatment unit for reprocessing*.

It was proposed to use with this aim the currently available cell for defective canisters (CDC) in the reprocessing shop of the plant RT-1, which has to be reconstructed:

- to develop the process of pre-treatment of spent fuel assemblies with various defects for reprocessing (including spilled fuel collection and SRW disposal);
- to design, manufacture and mount the necessary equipment;
- to equip the cell with additional accessories and tools for manual and remote handling.

FSUE “FCNRS” has completed preliminary process development for non-standard spent fuel assembly pre-treatment in the cell for defective canisters resulted in the conclusion of principal feasibility of such pre-treatment with compliance with current requirements concerning nuclear facilities.

After the pre-treatment in the cell for defective canisters spent fuel assemblies will be suitable for further reprocessing according to the routine process of the plant RT-1.

Liquid, solid and gaseous waste resulted from spent fuel assembly pre-treatment in the cell should be reprocessed according to the radioactive waste handling system applied in the plant RT-1.