

DESIGN OF INTERIM DRY STORAGE FACILITY FOR SPENT NUCLEAR FUEL FROM RUSSIAN NUCLEAR SUBMARINES

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ABSTRACT

The report presents the concept for construction of a Dry Storage Facility for interim storage of Spent Nuclear Fuel (DSF SNF) generated in the course of dismantlement of Russian Nuclear Submarines (SSBN). This design for construction of the first Russian up-to-date industrial container-type Dry Storage Facility for long-term storage of Naval SNF at PO “Mayak” is currently being developed within the framework of Cooperative Threat Reduction Program (CTR) at the Defense Threat Reduction Agency (DTRA).

The report gives the main technical and economic parameters of the Design. The Storage Facility is designed to accommodate 154 TUK-108/1 transportation/packaging sets manufactured according to the certified Russian process using specialized “heavy” reinforced concrete. The internal chambers of TUK-108/1 house the cases loaded with SNF. The TUK-108/1 casks are completely certified products designed for long-term storage of SNF. The casks are equipped with three sealing barriers ensuring safe storage of SNF. The Storage Facility is designed for 50-year operation. In compliance with the nuclear-fuel cycle concept adopted in the Russian Federation (RF), during the period of SNF storage in DSF, the SNF will be periodically delivered for processing to the Plant RT-1 also located at PO “Mayak”.

The transportation/process flow diagram for handling SNF in the DSF, including SNF preparation for long-term safe storage, is also reviewed in this paper. The Design provides for “know-how” allowing preparation of SNF without dismounting TUK’s internal sealing lid. This approach noticeably simplifies the process and reduces the risk of personnel exposure to radiation.

INTRODUCTION

The project on construction of an interim container-type dry storage facility for spent nuclear fuel (DSF SNF) from Russian nuclear submarines (SSBN) is implemented within the scope of

the Cooperative Threat Reduction (CTR) Program and answers the purposes of the “Concept for integrated dismantlement of SSBN and surface ships with nuclear power reactors” approved by the Government of Russian Federation (RF) in 1998. This design is to provide at PO “Mayak”, Ozyorsk, Chelyabinsk region, storage for approximately 154 transportation/packaging concrete-filled steel containers (TUK-108/1), which were earlier developed by Russian organizations under the Arctic Military Environmental Cooperation (AMEC) Program (main designer – OAO KBSM, St. Petersburg).

The main issue requiring a solution in the course of design development was the nuclear, radiation and ecological safety of SNF storage. In addition, in the design it was necessary to resolve the issues about minimization of the construction cost considering that it was predetermined to construct the Storage Facility in Building 301 at Plant 23, earlier used as “wet” storage for a plant specializing in the production of weapon-grade plutonium and now having fixed radiation contamination that is hard to remove. In order to resolve these issues we have envisaged a complex of engineering, design and organizational measures. The main devices ensuring nuclear and radiation safety of the storage are the TUK-108/1 containers. Their safety for SNF storage is supported with calculations of the strength, nuclear and radiation safety, airtightness, selection of structural materials and fabrication methods of TUK.

The containers represent completely certified items designed for long-term storage (up to 50 years) of SNF and are provided with three sealing barriers ensuring safe storage of SNF. The exterior of TUK-108/1 is given in Fig. 1.

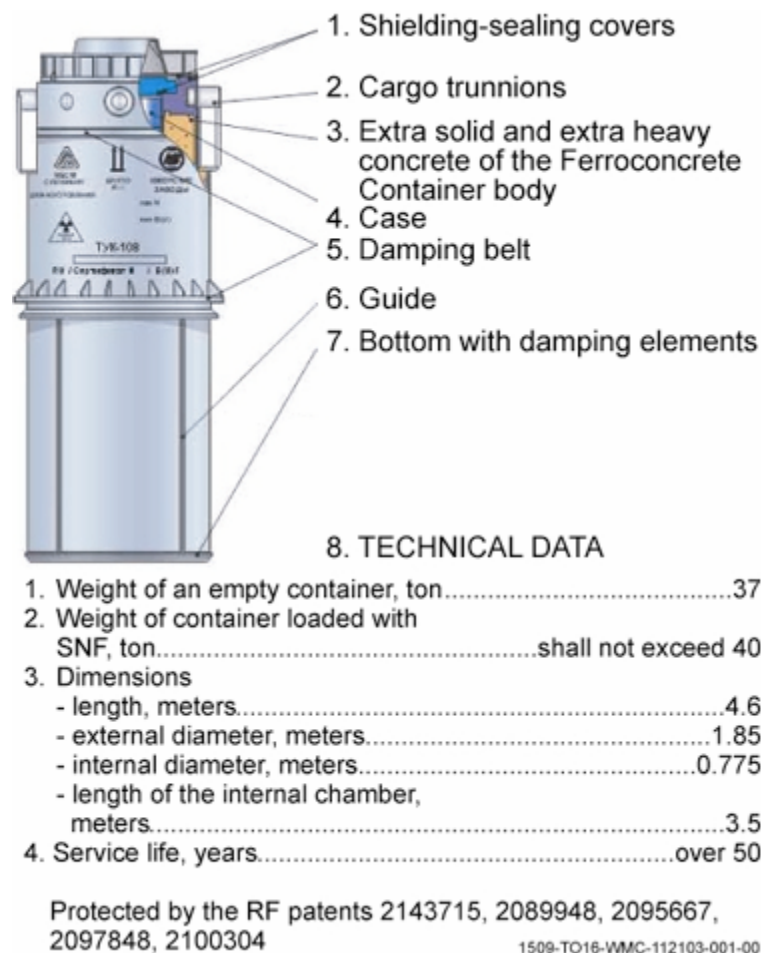


Fig.1 Reinforced-concrete navy container. Awarded with Gold Medal at Brussels-Eureka 2000 Exhibit. Designed by RF Federal State Unitary Enterprise “Design Bureau of Specialized Machine-building”

During the project implementation, studies have been conducted on using dry method for SNF long-term, which concluded that the SNF shelf life can reach five years and longer provided SNF is stored in inert dehydrated environment.

In this respect, a number of systems have been developed for preparation of SNF in containers prior to their long-term storage. These systems ensured container handling within the entire process cycle from reception of SNF in TUK for storage up to their dispatch for processing.

Main storage facility parameters

DSF SNF is designed to accommodate 154 TUK-108/1 containers, prepare them for long-term safe storage and store them for up to 5 years.

The storage effective lifetime is 50 years.

SNF from dismantled Generation I, II and III SSBN without fuel damage, (i.e., SNF with unimpaired claddings of fuel elements held for not less than 10 years) is received at the storage. The approximate quantitative composition of the fuel is as follows: the assemblies from Generation I, II and III contribute 17%, 61% and 22% respectively.

The SNF storage operates in the following modes:

- Mode I – reception and preparation of TUK with SNF for storage. A provision is made for the storage facility to be completely filled in two years;
- Mode II – storage of prepared TUK with SNF. This period will last for not longer than 5 years;
- Mode III – preparation of TUK with SNF for shipment and their delivery for processing to Plant RT-1 located at the site of PO “Mayak”.

The following assumptions were used to determine the rated parameters:

For Mode I, it is assumed that all 154 TUK containers with SNF from dismantled SSBN will come in special railcars TK-VG-18 (TK-VG-18A) to PO “Mayak” within two years in several equal batches scheduled with the same intervals between each other.

Mode II is determined by the regulation requirements for safe storage of SNF in TUK established by Gosatomnadzor (GAN) of RF. Concerning the issue of the certificates for storage of SNF in TUK, GAN has determined a five-year shelf life and issues respective permits. After expiration of that term the certificate shall be renewed in compliance with all procedures and warranties for the next five years. The conservative approach of GAN to the modes of long-term storage in many respects is determined by the fact that presently there is still no common practice for long-term dry storage of SNF in TUK. Therefore, such GAN requirements are quite justifiable.

Finally, Mode III corresponds to the concept of the “self-contained” nuclear-fuel cycle adopted in RF. According to this concept, SNF is a subject to re-processing. Therefore, SNF from SSBN will also periodically arrive at Plant RT-1 located at the same PO “Mayak”.

To perform material-handling operations, the storage has the following primary equipment intended both for TUK relocation and conduct of incoming inspection and routine maintenance.

- Special electrical bridge crane with lifting capacity of 50/12.5 t intended to move TUK and auxiliary equipment around DSF SNF.
- Lift bar with lifting capacity of 45 t intended to transport TUK with the bridge crane of lifting capacity of 50/12.5 t. Load-handling hooks of the lift bar are equipped with safety locks preventing spontaneous decoupling of the lift bar with transported TUK.
- Special electrical bridge crane with lifting capacity of 10 t intended to carry out the following process operations in the process compartment:

- preparation of TUK for storage (dismounting and mounting of the external lid);
- integrated routine maintenance to TUK during storage.

- Transfer dolly for TUK with lifting capacity of 50 t intended to deliver TUK from the storage compartment to the process compartment. The dolly travel is controlled from the control panel installed on the dolly. The dolly is equipped with:
 - safety device disconnecting the travel drive in case the dolly runs over an obstacle;
 - interlock enabling travel of the dolly only when the building gates are open.

Procedure for SNF handling in DSF SNF

The layout of the Storage Facility indicating the main transport/process operations, such as reception, preparation for storage and dispatch for processing of SNF SSBN in TUK-108/1, is given in Fig. 2.

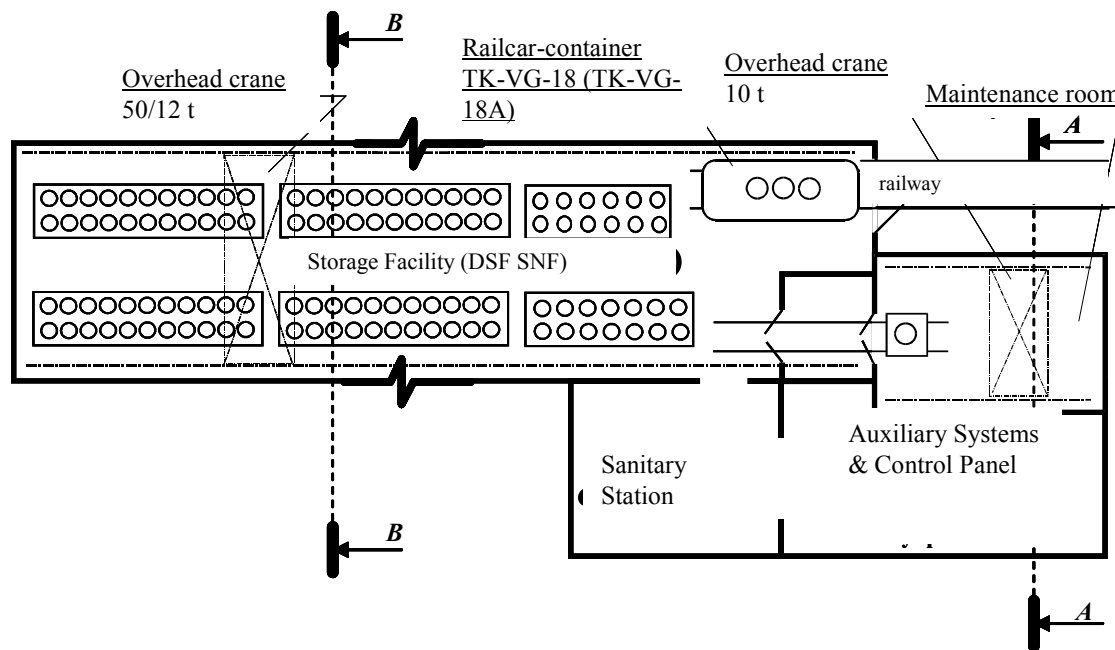


Fig. 2 Schematic layout of the designed dry storage facility in Building 301, PO “Mayak”
Sectional views A-A (See Fig.3.) and B-B (See Fig.4.).

Each special train with TUK, upon its arrival at the PO “Mayak” site, is broken up, and four or six railcar-containers with TUK are hauled consecutively by the locomotive to DSF SNF. In the wintertime the railcars are warmed up in the neighboring building. Then the railcars are hauled for unloading into DSF SNF and the multi-step acceptance inspection of TUK is carried out including:

- visual inspection of TUK to check for possible damages during transportation;
- checking availability of seals;

- measurement of the level of the maximum dose rate of neutron- and gamma-radiation of radionuclides on TUK surface.

Upon inspection completion, the following information on the received TUK is entered into the automatic accounting and control system:

- certificate for spent fuel assemblies (SFA) loaded in canisters;
- certificates for canisters;
- charts for loading of canisters with SFA;
- certificate for TUK loaded with canisters with SFA;
- logbook for TUK;
- charts for loading of TUK with canisters with SFA;
- records of TUK leak tests (relevant to express-control of air-tightness for internal and external lids of TUK);
- records for control of neutron and gamma-radiation levels and radiological contamination level of TUK external surface;
- logbook for sealing TUK.

All these operations are carried out in the compartment dedicated for temporary storage.

After their completion TUK in turn shall undergo the most critical and complex procedure – preparation for long-term storage. It is performed in the TUK preparation area (Fig. 3) specially equipped with the following process systems:

- system for “vacuum drying” of intra-container and intra-canister spaces;
- monitoring system for air-tightness of seals;
- system for fill-up of intra-container and intra-canister spaces with inert agent.

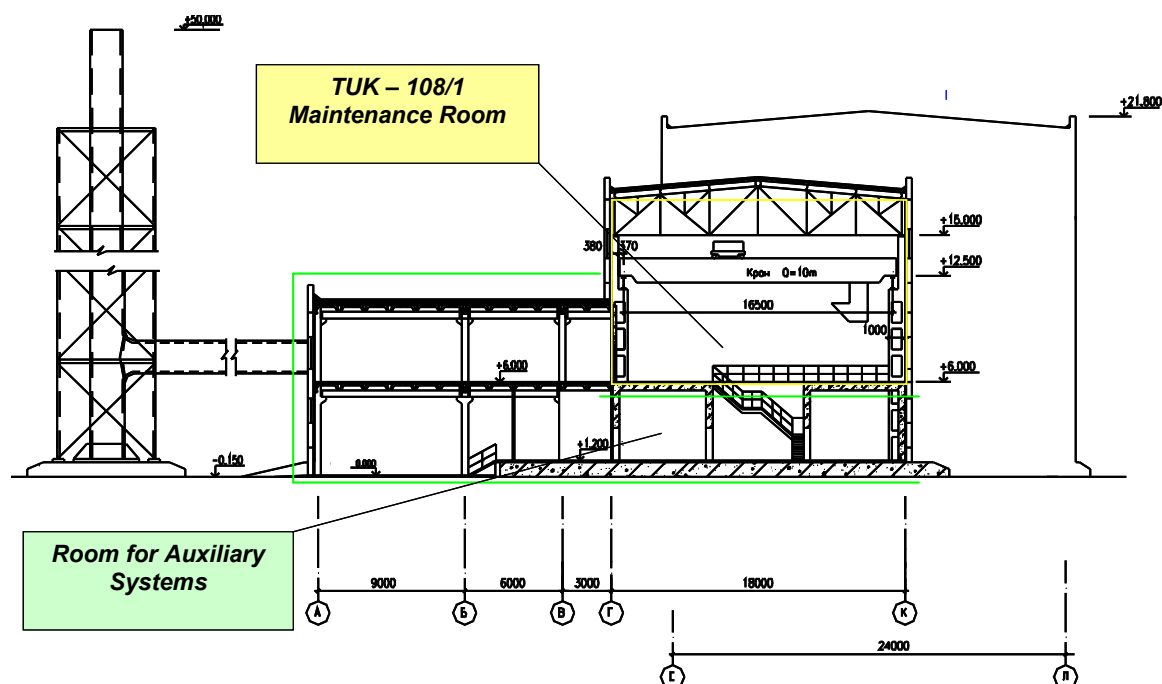


Fig.3 Schematic layout of TUK-108/1 acceptance and maintenance rooms in dry storage facility for Spent Nuclear Fuel

The procedure for preparation of TUK with SNF is conducted in the following sequence:

TUK is placed by the 50/12.5-t crane on the special transfer dolly and transported from the temporary storage compartment to the storage area. In the storage area there is a maintenance compartment, where special operations on preparation are carried out. They include applying negative pressure to the internal spaces of container and canisters for practically total removal of the residual moisture from there, their purging and filling the internal hollow of TUK and canisters with inert gas (argon or nitrogen) up to pressure of 0.08 MPa.

Then the air-tightness of TUK internal chambers is monitored according to the operating manual for TUK-108/1.

If the previous operations have shown their reliability, then, TUK intra-lid space is filled with inert gas and air-tightness of the entire TUK is monitored one more time. The final value of the pressure parameter in TUK intra-lid space is recorded in the TUK-108/1 logbook, entered in the automatic monitoring system of air-tightness and is used as a basic parameter for the entire duration of SNF interim storage in DSF SNF.

Finally, seals are installed on the bolts of lid fastening and valves of TUK, and radiological contamination level of TUK external surface is measured. In case of recording an excessive radiological contamination level, decontamination is performed using the equipment specifically provided as a part of the storage facility package.

Then TUK with SNF is transported from the preparation area to the storage area (Fig. 4), where TUK is connected through a pressure sensor to the standard storage control and monitoring system.

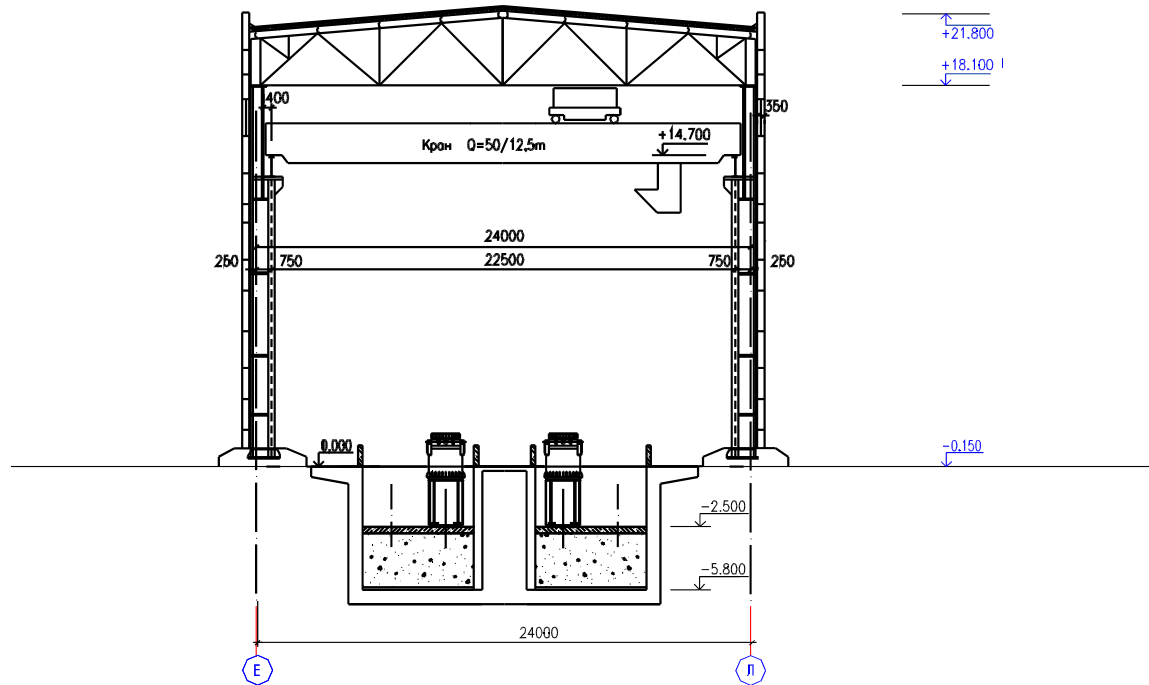


Fig. 4 Schematic layout of storage room for TUK-108/1 loaded with SNF in the dry storage facility for spent nuclear fuel. Designed to accommodate 154 TUK Casks

The following data are entered in the storage control and monitoring system: No. of TUK storage seats, No. of TUK containers, types and quantity of canisters loaded in TUK, type and characteristics of SFA located in canisters. The similar operations are performed with all TUK containers coming for storage. After completion of activities concerning installation of TUK for storage, the radiation dosimetry monitoring of surfaces of storage and service areas and, if required, decontamination of these premises is performed.

Containers are stored in a heated room divided by protective reinforced-concrete partitions in eight cells (Fig. 2). This solution is determined by necessity to conduct automatic monitoring of the following parameters in the premises during storage:

- gas pressure in TUK intra-lid space. The system informs the operator about excess of the pressure in the intra-lid space beyond the established boundary values and the rate of gas pressure change;
- temperature of air in compartments.

It should be noted that all the special systems for preparation of TUK with SNF for long-term storage are referred to as technologically unique systems. Each includes dozens of units of

special and high-precision equipment. They are developed for this project for the first time. As they fall into the category of systems relevant for nuclear safety, the detailed design documentation is a subject to the complex procedure of coordination and approval with regulatory and supervisory bodies of RF.

CONCLUSION

In conclusion it is necessary to briefly focus on the current status of the design. DSF SNF design has now successfully passed all the stages of coordination and approval at the regional and federal levels. A positive conclusion of the State Environmental Expert Council is obtained for this design that demonstrates a high scientific and technical level of design development.