

**Nuclear Safety Institute of the
Russian Academy of Sciences
(IBRAE RAN)**

Annex 9

Source Control Project, Phase III

Task 2

Milestone 8

Project Management Plan for FSUE "EE "Zvezdochka"

***Risk Assessment at the Coastal Unloading Facility of FSUE "EE
"Zvezdochka"
Final Report***

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Moscow
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Report

Summary

Annex 9 (Source Control Project, Phase III) covers the activities on development of methodology and conduct of risk assessment on the example of radiation and chemical hazardous facilities of the industrial North of Russia. This annex continues the works on the source control project, which were started in 2000.

Two major facilities of the North of Russia were chosen for the current project: FSUE "EE "Zvezdochka" (Severodvinsk, Archangelsk Region) and FSUE "Atomflot" (Murmansk).

The main activities of FSUE "EE "Zvezdochka" are connected with repair, modernization and decommissioning of nuclear and diesel submarine of both Russian and foreign manufacture.

FSUE "Atomflot" carries out maintenance and repair of nuclear powered vessels and nuclear maintenance vessels. In addition to general ship repair, the facility performs unloading, temporary storage and processing of liquid and solid radioactive waste, storage and transportation of spent nuclear fuel, repair and storage of special rigging.

Task 1 of Annex 9 included the works on organization and conduct of the 1st visit to the site, selection of a facility for application of risk assessment, development, coordination and signing of PMP, preparation and conduct of training courses on methodical foundations of risk assessment for the personnel of facilities of this type of activities in the North-West Region of Russia.

PMP for FSUE "EE "Zvezdochka" was approved on November 9, 2005.

PMP for FSUE "Atomflot" was approved on May 29, 2006.

Works on Task 2 of Annex 9 are carried out in accordance with the PMP for the studied facilities.

The goal of Stage 8 of PMP for FSUE "EE "Zvezdochka" is to prepare the final report on the risk assessment, which should include the recommendations on the possible use of ISO 14001 standard and the developed risk methodology document.

The current report is presented in accordance with the report documents of Stage 8 of the PMP for FSUE "EE "Zvezdochka".

Input information

The work is implemented in accordance with the Risk Assessment Methodology developed in the framework of earlier Phase I and Phase II of the Source Control Project (2000-2004).

The first stage of the project was conducted at a sewage facility of the town of Apatity in the Murmansk Region of the Russian Federation. A draft of Risk Methodology Document for the chemically-hazardous industrial facilities was developed as a result of the project.

The second stage of the project was conducted at the fuel research department of FSUE "SSC RF Nuclear Reactor Institute" in Dimitrovgrad of Ulyanovsk Region. During the execution of this project the risk assessment methodology was adapted to the radiation-hazardous facilities.

The current stage is implemented in accordance with the risk assessment methodology document and is the final stage of the works under Phase III of the Source Control Project at the coastal unloading facility of FSUE "EE "Zvezdochka".

Scope of Work

Nuclear- and radiation-hazardous works carried out at FSUE "EE "Zvezdochka" are mainly connected with the program of decommissioning NS withdrawn from the Navy. The main works connected with unloading, transportation, and temporary storage of SNF are carried out at the coastal SNF unloading facility, which is examined in the current project.

The works carried out in the framework of stage 8 were aimed at execution of the following main tasks:

- Development of recommendations on introducing the ISO 14001 standard into the environment management systems and the use of risk assessment methodology in the process;
- Preparation of the final report

Scope of Work Details

The current section gives a brief description of the studied facility, the performed works and the recommendations received in process of project implementation.

The more detailed information may be found in the reports on stages 4-6, prepared according to the PMP for FSUE "EE "Zvezdochka".

1. General Description of FSUE "EE "Zvezdochka" and the Coastal Unloading Facility

Federal State Unitary Enterprise Engineering Enterprise "Zvezdochka" is the leading Russian shipyard in the field of repair and refit of submarines, surface ships of various classes and purposes. Over the recent years the facility has been also engaged in construction of fishing trawlers, floating piers and drilling vessels for production of oil and gas in the shelf of the Russian Arctic Seas.

The facility is located in the town of Severodvinsk on the Yagry Island 35 km to the west of Archangelsk in the delta of the Severnaya Dvina River.



Fig.1. Region of FSUE "EE "Zvezdochka" location

In accordance with the SALT-1 Agreement between Russia and USA FSUE "EE "Zvezdochka" is the only facility in the North region of Russian authorized to decommission the ballistic missile launch tubes of NS. The facility has been involved in dismantling missile compartments of nuclear submarines and comprehensive decommissioning of NS in the framework of international agreements on limitation and reduction of strategic offensive weapons since 1977.

The fuel from the submarines until recently has been unloaded using the specialized naval floating base launched in 1960. The equipment of the floating base was insufficient to ensure implementation of the approved program of NS decommissioning. In order to resolve this problem, FSUE "EE "Zvezdochka" and the Threat Reduction Agency of the US Department of Defense have signed the Contract for design and construction of the coastal facility for unloading SNF from the NS reactors. The facility was commissioned in 2002. The documents regulating the works on unloading SNF form the decommissioned submarines were developed by FSUE SI RDIPT (St-Petersburg) and FSUE RDTB "Onega".

At the current time the main works connected with unloading SNF from the NS reactors are carried out at the coastal unloading facility, which is examined in the current project.

Elements of the coastal facility for SNF unloading

The infrastructure of the coastal SNF unloading facility is shown in fig. 2. The figure also shows the cycle of SNF management used at the facility. The facility includes the following coastal utilities and structures:

1. Section of a special mooring line about 40 m long equipped with a new portal crane of 80 t lifting capacity. A decommissioned NS and the floating monitoring and dosimetry station (FMDS) are moored within the operating range of the crane.

2. Building for loading of transport containers, which is located in the immediate vicinity of the special mooring line within the operating range of the portal crane. A trailer route to the building is provided. The building includes two process sections with a width of 12 m, length of 24 m and a 3-storied annex housing the unloading control post, sanitary checkpoint, ventilation chambers and other auxiliary rooms.

The first section includes the TUK loading hall with two loading stations. The stations are used to execute the following works

- Placing an empty transport container onto the transportation carriage with a portal crane and its further transportation to the loading station using the bridge crane with a 50 t capacity;
- Opening container, removing the lid;
- Removal of the shrouds from the container, verification of their conformance to the technical requirements and loading the verified shrouds into the container;
- Mounting of a guiding device onto the container;
- Loading SFA removed from the reloading container into the shroud cells of the transport container;
- Removal of the guiding device, sealing the container, closing the lid;
- Transportation of the container loaded with SFA with a bridge crane of 50 t capacity, placement on the rail car with the 50 t capacity, which is rolled out of the building into the area of portal crane operation.

The second section equipped with a crane of 16 t capacity is used to store the reloading equipment and prepare it for operation. Ventilation chambers are located at the height of +10.8 m over the second section.

3. Temporary storage pad for transport containers with a capacity to hold 30 containers. TK-18 or TUK-108/1 containers are located in a special closed unheated building with a sectional roof. The dimensions of the building are 22x8x6.5 meters. Section of a railway providing loading of four TK-VG-18 container cars and access routes for trailer are provided. The pad is equipped with a crane with a 50 tons lifting capacity, which is used to load and unload the containers from the railway cars and the trailer. There is also a checkpoint, security systems, as well as security and fire alarms at the pad.

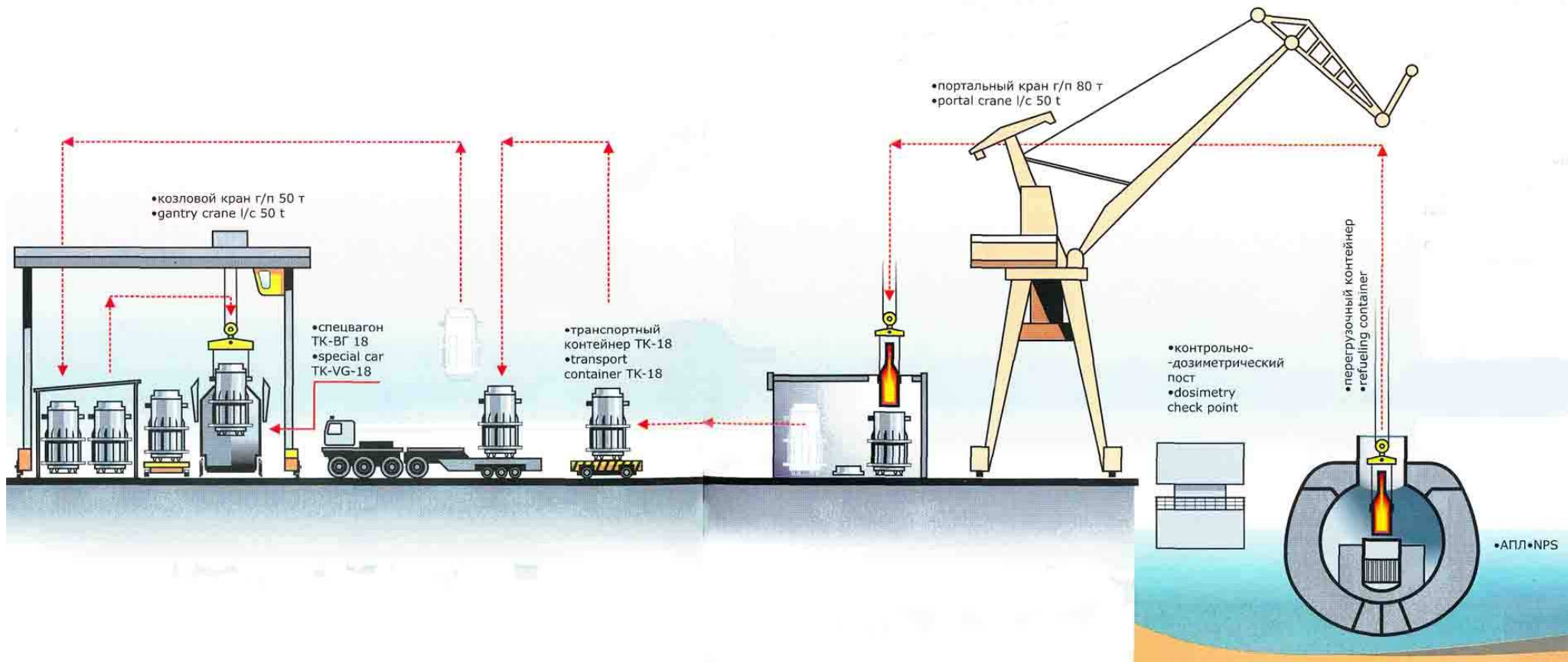


Fig. 2. Infrastructure of FSUE "EE "Zvezdochka" coastal unloading facility

2. Preliminary risk assessment

The preliminary risk assessment stage was used to study the various initial events and the possible accident evolution scenarios to select the most significant ones for further quantitative risk assessment. The following initial events have been selected: loss of power supply during SNF reloading, fire, extreme external impacts, fall of various equipment elements.

Total loss of Power Supply

Two independent sources are used to supply power for the equipment used in SNF management operations: the city power plant and from the main scaling substation of the Yagry island. A reserve diesel power plant can be used if power supply from both sources is cut off.

The following SNF management elements require power supply:

- lifting cranes;
- transportation carriage;
- electric motor of the system for removal of water from shrouds and TK-18 containers;
- electric motor of TK-18 container airtightness monitoring system;
- pneumatic nutrunners.

In accordance with the requirements of it. 2.4 [1] the mechanisms for load lifting and change of the crane radius are equipped with closed type brakes, which are automatically disconnected if the actuators are engaged and automatically connected if the actuators are turned off. Thus the loss of power supply will cause the SNF container to stop movement until another power supply is engaged.

Results of thermal calculations performed for TUK-108/1 transport package [2] at the least favourable long-term storage conditions (ambient temperature 38 °C, solar insolation and calm conditions) demonstrated that the sealing elements of the I and II airtightness circuits of the transport package TUK-108/1 remain functional.

Loss of power supply to the electric motor of the system for water removal from the shrouds and containers does not affect the safety of the carried out works. The works are stopped until the power is restored or a reserve power supply is connected.

Loss of power supply to the electric motor of the TUK-18 airtightness monitoring system does not affect the safety of carried out works. The works are stopped until the power is restored or a reserve power supply is connected.

Failure of the air supply system feeding compressed air to the pneumatic nutrunners does not affect the safety of carried out works, but leads to temporary interruption of the operation. The screws holding the lid of the TK-18 container may be screwed manually using the calibrated wrench.

Fire

The fire may occur as a result of both external impacts, and internal failures. The fire may lead to failures of the equipment, and power supply systems. The fire may be caused by short circuiting of the power supply cables, oil falling on hot sections of the equipment, ignition of fuel and lubrication materials, and personnel errors during repair and restoring works.

The following actions should be taken to prevent the fire:

- Inflammable and nonflammable materials are used in the infrastructure of SNF management.

- Storage and use of flammable materials is carried out under strict control;

- All fire-hazardous works (welding, etc) are carried out under strict control.

No repair works requiring open flame sources are allowed for the period of operations on management of SNF.

Fire at a load-lifting crane may lead to failure of its elements and, consequently, fall of the lifted SNF container. Fire at the transportation carriage will not cause the fall of the TK-18 container.

Analysis of the amount of flammable materials stored at CUF and in its immediate vicinity demonstrated that the scale (temperature, time) of the potential fire connected with the process factors will not be sufficient to cause loss of container airtightness (See Attachment 2).

TK-18 container may lose airtightness in a fire only as a result of extreme external impact, such as crash of an aircraft with a sufficient amount of fuel on board.

Special inorganic powders and carbon dioxide fire-fighting equipment is required by the regulations if the TUK-18 packages are located in the fire area or in its immediate vicinity. Radiation situation monitoring is carried out during the works, and individual protection equipment (isolating gas masks, protective clothes and shoes) is used.

Seismic impact

According to the "Map of seismic zoning of the European part of the USSR", Severodvinsk city is located in the area where a design-basis earthquake of maximum magnitude of 6 points according to the MSK-64 scale is possible. Taking into account the soil conditions of the site, the magnitude of maximum design-basis earthquake was taken as 7 points according to MSK-64 scale in compliance with the Appendix No. 3 NP 031-01 [3].

The parameters of maximum calculated earthquake were calculated to determine the possibility of package overturning as a result of an accident. The corresponding procedure is given in the document "Typical set of synthesized accelelogramms simulating eight-point shaking", developed by the Institute of Physics of the Earth of RAS in cooperation with "Atomenergoproekt" and "Gidroproekt" institutes.

The calculations showed that a maximum design-basis earthquake will not lead to overturning of the TUK-18 package.

Analysis of mechanical impacts connected with the earthquake and fall of structural elements of buildings and equipment on the packages showed that these impacts are substantially lower than the design-basis impacts given in Attachment 2.

Fall of equipment elements

The following equipment elements may fall during the transport and technological operations on SNF management at CUF, leading to damage of the SFA or fuel element claddings:

1) Reloading container during the loading of TK-18 container with SFA. A guiding device is installed on the container in this case;

2) Guiding device on the container with shrouds fully loaded with SFA. Such a fall may occur when the guiding device is removed from the container upon completion of TK-18 container loading.;

3) Container lid on the container with shrouds fully loaded with SFA. The fall may occur when the container lid is installed on the container upon completion of the loading operations.

4) Guiding device cross-arm on the guiding device. The fall may occur when the cross-arm is moved for connection with the guiding device.

5) Container lid cross-arm on the container lid installed on the loaded container. The fall may occur when the cross-arm is removed from the container lid.

Fall of elements 4 and 5 are not taken into account in subsequent analysis, as their weight is substantially lower than that of the reloading container.

Fall of the container lid (3) may also be taken out of the consideration as the weight of the lid is three times lower than the weight of the guiding device, and the height of their fall is nearly the same.

A guiding device is located on the container if the reloading container falls in process of TK-18 container loading. The shrouds are taken as fully loaded for the moment of reloading container fall in order to make a conservative assessment. The cases are not plugged. SFA do not protrude from the removable part of the container. The gap between the lower surface of the guiding device and the removable part of the container is at least 400 mm. The height of the fall is 12.5 m if the TK-18 container is loaded through the building hatch.

The guiding device strength assessment demonstrated that a fall of the reloading container onto the guiding device does not lead to its destruction and does not affect the position of SFA or the integrity of SFA and fuel element claddings.

The impact of a crane falling on the container as a result of an earthquake may lead to container losing integrity. The consequences will be especially severe if the package was open during the impact. Both the first and the second events are possible only during the works and thus are virtually improbable even without taking into account the probability of direct hit of the container by crane elements.

Fall of equipment elements containing SFA

The following events and scenarios connected with the fall of equipment elements containing SFA are possible in process of transport and technological operations:

- Fall of a single SFA into the TK-18 loading room;
- Fall of reloading container loaded with SFA;
- Fall of TUK-18 package.

Fall of a single SFA into the TK-18 loading room. The procedure of loading TK-18 containers with SFA is organized so that only a one SFA at a time is loaded into the container. At the same time, the guiding device installed on the container protects the SFA loaded earlier. SFA may fall only in process of loading into the shroud. This accident is considered as a design-basis accident. It is assumed that 100% of fuel elements in a SFA lose airtightness for a conservative assessment. 100% of the radionuclides contained in the gap are released from beneath the claddings. Assessments for the most significant radionuclide, Kr-85, show total activity around 1 TBq in the absence of fire.

As the SFA falls into the shroud installed on the removable part of the container, no intense release of fission products into the loading room occurs. Assessments show that, taking into account the rate of radioactive substances release from the inner cavity of the container and work of the special ventilation system of the loading room (air exchange 10 times per hour), the actual values of the dose loads on the personnel will not exceed the allowed values.

Fall of reloading container loaded with SFA. It is assumed that 100% of fuel elements in a SFA lose airtightness when the reloading container falls. Assessment of radionuclide release into the environment is similar to that for the case of SFA fall. However, in this case, the consequences for the personnel will be higher because the damaged SFA will be located outside the transport package and this scenario may be considered more significant.

Fall of TUK-18 package. Only a single TUK-18 package is transported at a time according to the technological procedure. The package is sealed and monitored for airtightness prior to transportation. The amount of water inside the package should be lower than the allowed values. Currently a transportation carriage is used to transport TUK-18 from the loading facility to the temporary storage room. For all possible cases of fall of TUK-18 (in case of transportation on the carriage and fall from it, in process of loading to the railroad carriages and transportation

to PA "Mayak"), the maximum height of the fall is 5.5 m. This value is substantially lower than the maximum design-basis lifting height (see Attachment 2), thus guaranteeing the airtightness and integrity of the packages.

Thus, the following scenarios were chosen for preliminary risk assessment on the basis of the hazards identified at CUF:

- Fall of reloading container loaded with SFA
- Fall of a guiding device onto TK-18 container;
- Impact of an aircraft crash on SNF unloading facility

3. Assessment of the probability of initial events

Fall of reloading container loaded with SFA

This scenario is realized only in case of rupture of two cables of double polyspast used in the lifting crane. Each of the cables will hold the container from falling.

Preliminary analysis showed that the fall of the reloading container may be the result of equipment failure due to wear or a personnel error. Extreme external impacts and occurrence of a fire leading to rupture of cables are virtually improbable for the period of execution of the works.

No cases of fire were recorded at the CUF during the whole period of its operation.

The following measures are directed at reducing the probability of occurrence of emergency situation caused by personnel errors:

- Training of the personnel in working with the TUK-18 package using the emulators;
- Use of specially designed and certified gripping devices (cross-arms) for operations connected with the movement of SFA;
- Check of the correct fastening of the gripping device with the transported load after it is lifted to the height not exceeding 300 mm;
- Monitoring of correct implementation of the operation instructions by service personnel carried out by the head of works.

In order to reduce the probability of crane operator errors, the crane is equipped with devices limiting the lifting height, lifting rate and boom turn rate. Blocking operations is used for the same purpose - the crane allows execution of only one operation - either the lifting or turning of the boom.

No accidents connected with the fall of a container loaded with assemblies have occurred at FSUE "EE "Zvezdochka". Three such accidents occurred over the whole period of works on reloading of NS reactor cores in Russia (and the Soviet Union). Taking into account the overall

scope of works on reloading of the fuel over these years (around 1000 cores), the probability of fall of a container loaded with SFA during its reloading from the NS can be conservatively assessed at the level of $6 \cdot 10^{-3}$. This will be taken as the base assessment.

In the last years the facility unloads the cores from 4 NS per year in average. Thus, the probability of fall of the container loaded with SFA can be assessed as $2.5 \cdot 10^{-2} \text{ year}^{-1}$.

Guiding device on the container with shrouds fully loaded with SFA

If the guiding device falls and directly hits the centre of an open and fully loaded TK-18 container with a 90° edge, the central shroud holding 7 SFA will be damaged.

No cases of fall of a guiding device were recorded during the whole period of works on reloading of reactor cores.

The following sequence of events is required to realize this scenario. The first one is the failure of one of the three cable bindings. This must be immediately followed by a 90° turn of the guiding device with subsequent failure of the two remaining bindings. Furthermore, the device should fall directly into the center of the container. All of these events must happen immediately one after another in very short time intervals.

Similar scenario should be realized for the fall of the container lid, however its weight is three times lower.

Assessment of the dynamic load on the remaining two cables was carried out by resolving differential equation of rotary motion in model geometry.

The solution of the equation in the lowest point for a circle of mass m connected to two immobile hinges secured at the angle of $2\pi/3$ is as follows

$$F = (1 + 121/150) \cdot mg ,$$

where F is the dynamic load on the cables for the moment the device passes the lowest point.

Substituting m with the value of 8300 kg we will get the maximum load on the cables as 15 tons. This value is lower than the design-basis allowed loads for this equipment (see Attachment 2). This assessment can be used to state that the simultaneous rupture of the two remaining cables is not a determined consequence of the first failure. These events can be considered as independent and caused by the wear of equipment or personnel errors.

Thus, the probability of damage of SFA shroud may be assessed as *the probability of the shroud being loaded x probability of failure of a single binding x probability of simultaneous failure of the two remaining bindings within a short period of time x probability of correct orientation of the surface of the device.*

The probability that the shroud is loaded is $1/7$. The probability of the correct orientation of the surface of the device may be roughly assessed as $1/p$. If we use the base assessment for the fall of container with SFA, the probability of fall of this scenario can be assessed as $7 \cdot 10^{-7} \text{ year}^{-1}$.

The probability of this scenario may also be assessed on the basis of the standards of faultless operations (0.9999), which is recommended [4] for the elements of hoisting equipment in the cases when a failure may lead to an accident.

Taking into account that: TUK-18 holds a quarter of the reactor core, 7 such operations should be carried out and the facility decommissions 4 NS per year in average, each having two reactors, the average number of operations is approximately 250. Thus, the probability of a single failure can be assessed as $2.5 \cdot 10^{-2} \text{ year}^{-1}$, which coincides with the base assessment for the probability of fall of the reloading container.

Thus, the probability of fall of a guiding device on a container and destruction of the central shroud holding 7 SFA is assessed at the level of $5 \cdot 10^{-6} \text{ year}^{-1}$.

Impact of an aircraft crash on SNF unloading facility

According to [5] the probability of an aircraft crash within an area of 10000 m^2 in any region of the country is assessed as 10^{-6} per year. The parameters of the SNF unloading facility are substantially lower. Taking a conservative assessment of the area of the SNF unloading facility as 1000 m^2 and taking the given above probability value, the probability of an aircraft crash within the SNF unloading facility is assessed as 10^{-7} per year.

4. Assessment of the scenario consequences severity

Detailed assessment of the consequences of the scenarios considered above is given in the report on stage 5 of the Project management plan for FSUE "EE "Zvezdochka"). Assessment of the population exposure doses was carried out according to the Pasquille-Guifford model at the conservative assumptions. The current section lists only the main results obtained at the previous stage.

Fall of reloading container loaded with SFA

The annual effective dose for the population at the distance of 1 km (minimum distance to residential area) as the result of the accident will be in around 10 mSv, which is two orders of magnitude lower than the dose limit set for the population by NRB-99 [6]. Maximum effective dose for the personnel does not exceed 5 mSv, thus being 4 times lower than the basic dose limit set for professional exposure by NRB-99 [6].

This event is assessed as level 1 according to INES scale because of the multilayer protection criterion.

Fall of a guiding device onto TK-18 container

The radiation consequences of such an event include contamination of soils outside the control area by Cs^{134, 137} to the level of 1.6 Bq/m². The expected individual effective dose for the population without accounting for food chains (the lands within the radius of 5 km are not used for agricultural purposes) will not exceed 3.7·10⁻⁴ Sv. The personnel exposure dose within the radius of 100 m from the location of the accident will not exceed 8.3·10⁻² Sv.

This event is assessed as level 2 according to INES scale because of the on-site impact criterion.

Impact of an aircraft crash on SNF unloading facility

The values of effective doses received by the personnel in case of an accident do not exceed the annual limit set by NRB-99 [6] for the personnel (20 mSv/year), but are comparable with this value.

Effective doses of population exposure are about several tens of microsieverts, about 1-2 orders of magnitude lower than the annual dose limit for the population.

This event is assessed as level 2 according to INES scale because of the on-site impact criterion.

5. Risk Matrix fo CUF of FSUE "EE "Zvezdochka",

Table 1 gives the results of quantitative risk assessment for the most significant scenarios of accidents at CUF

Table 1. Results of quantitative risk assessment at CUF

Scenario No.	Initial event	Probability, year ⁻¹	INES scale level
1	Fall of reloading container loaded with SFA	2.5·10 ⁻²	2
2	Fall of a guiding device or a container lid onto TK-18 container	5·10 ⁻⁶	1
3	Impact of an aircraft crash on SNF unloading facility	10 ⁻⁷	2

Risk matrix was drawn up in accordance with the Risk assessment methodology document, developed during the work on Phase II of the Source control project. Priority matrix

of corrective actions for transport operations at CUF of FSUE "EE "Zvezdochka" is given in fig. 3. The scenario numbers in fig.3 correspond to table 1.

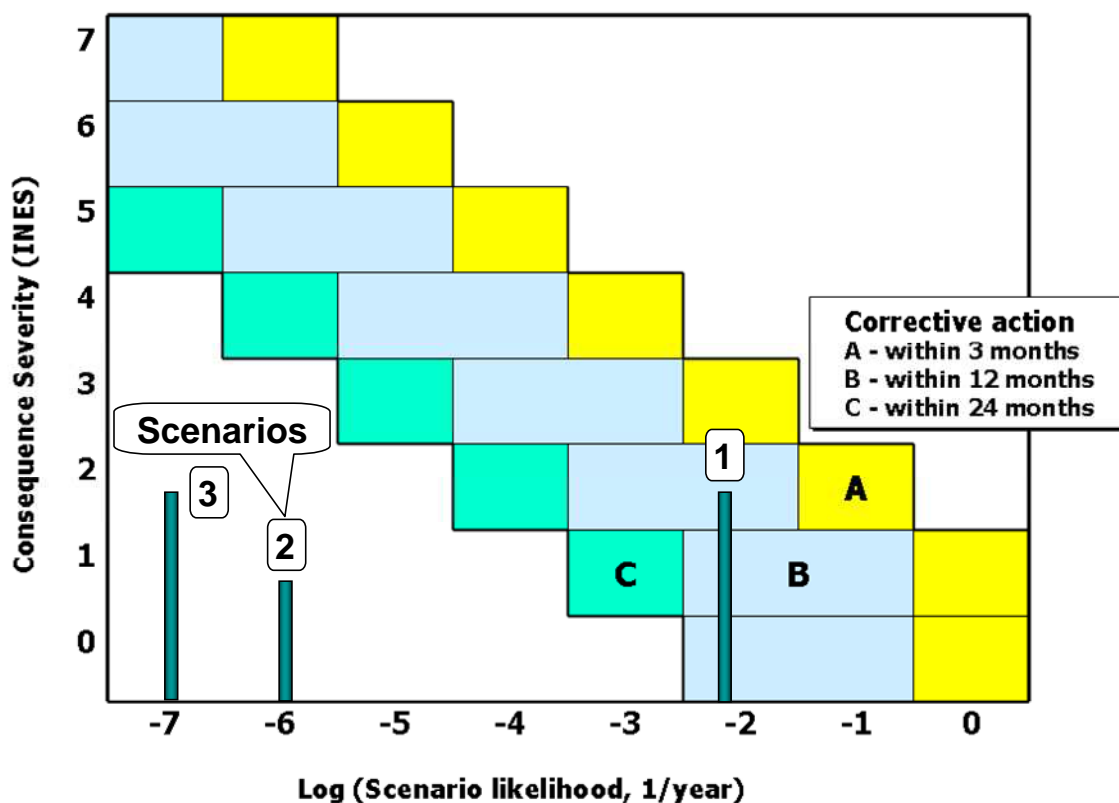


Fig.3 Risk Matrix for CUF of FSUE "EE "Zvezdochka"

The risk matrix shows that there are no scenarios which require implementation of urgent (within 3 months) corrective actions. The most critical scenario from the point of view of safety is scenario 1 – fall of the reloading container loaded with SFA. Corrective actions for this scenario may be assessed as planned measures. These works may be planned by the facility in this year and implemented within next year. The two other scenarios are located in minor risk area, where the implementation of additional corrective actions does not guarantee the reduction of risk.

6. Recommendations on Risk Reduction at CUF of FSUE "EE "Zvezdochka"

The executed analysis of accident risks in management of SNF at CUF show that the facility has a high level of safety. There are no scenarios which require implementation of urgent corrective actions. Thus, the main objective of the activities should be upkeeping the current level of safety and gradual risk reduction, which can be done in the framework of annual safety assurance programs.

To reduce radiation accident risk at the CUF, the working team recommends to consider the following proposals:

1. To equip the hatches on the roof of the building of shipping cask loading with electric motors for the purpose of automatic opening during SNF unloading (at present this work is performed by crane-operator), and to make changes in appropriate regulations.

2. To equip operators' cabins with acoustic alarm. The acoustic signal should change depending on performed operation.

3. To collect more detailed statistics of work order violations during SNF unloading, including personal explanation of violation causes by specialist, time of its unbroken work before violation, external conditions (for example, weather conditions). To analyze information for determination of expediency of gradual shortening of personnel working time.

4. To apply social technologies forming motivational preparedness to safe and quality work. For example, to develop the schedules of periodic specialist visits to psychologist on the staff for testing or psychologic relief.

All recommendations developed in the framework of this project are aimed at reduction of initial event probability. Taking into account general high level of the works and the fact that developed recommendations have direct or indirect influence on all transportation operations, the working team consider that developed recommendations have equal priority. Recommendation 2 is advisable to perform first for the portal crane.

Comparative analysis demonstrated that the formerly used procedure involving fuel unloading to the FMB was characterized with an elevated risk level, first of all concerning the external impacts. Introduction of SNF unloading procedure involving CUF in 2002 has lead to considerable reduction of the probability of the possible accidents and elimination of a number of initial events connected to transportation and reloading SNF to FMB. According to the data of the report [12], the safest procedure is SNF unloading at the facility slipway. This procedure was used in process of "Kursk" NS decommissioning, due to extensive damage of the submarine. However, such a procedure is the most costly one and can only be recommended for future consideration.

SFA can be damaged not only during SNF management at the CUF, but also earlier, during the floating storage of NS at the naval base or at the facility, e.g. as a result of reactor coolant system failure.

A fire at the NS during SNF unloading may have severe consequences.

The NS and the scenarios described above were not considered in the current project. Nevertheless, the working team recommends to carry out a joint analysis of the NS upkeeping works and fire safety assurance during the floating storage period in cooperation with the

specialists of involved ministries and departments. In order to prevent such accidents, the ship should be cleared of flammable materials, electricity sources and the power supply should be cut off for all the equipment which is not critically important for NS safety. Regulations on maintenance of the ship and fire-extinguishing systems should be available for the case of long-term NS floating storage.

7. Recommendations on the Use of Risk Assessment Methodology at FSUE "EE "Zvezdochka"

The methodology developed in the framework of the Source Control Project (Phases I-II) was applied for risk assessment at the SNF coastal unloading facility. Taking into account the universal approach taken in the methodology and the experience of its application, it can be recommended for other hazardous process facilities of FSUE "EE "Zvezdochka". These facilities include not only the radiation-hazardous ones, such as the LRW and SRW processing utility or LRW storage facility, but also such facilities as non-ferrous metals processing section or the section of thermal or mechanical cutting. The methodology document demonstrates a risk matrix example for such facilities. Regardless of the nature of the hazard sources, the risk assessment procedure includes several sequential stages described in the methodology. The experience shows that there are a number of problems that can be encountered at the stage of quantitative assessment of realization probability for some of the scenarios, which is mainly due to the difficulty in accounting all the risk factors and the lack of the required initial data.

The current methodology can be useful in introduction of the ISO 14001 standard at the facility at the stage of identifying and ranking the significant environmental aspects. Use of the risk matrix as a tool for identifying priority measures aimed at reducing the environmental impact allows developing a more efficient program for risk management and realizing the basic ISO 14001 principle, which is continual improvement.

8. Recommendations on Introduction of ISO 14001 standard at FSUE "EE "Zvezdochka"

At present, ISO 14001 International Standards allow facilities to implement the elements of efficacious environmental management system (EMS) which could be included in existing management system and coordinated with other works (production activity, finances and economy, product quality, population health protection, safety engineering, etc.). The recommendations on EMS implementation as well as potential benefit from EMS use at nuclear and radiation hazardous facilities were adequately expounded in the final report on Source

Control Project, Phase II. The recommendations for specific facility, namely FSUE "EE "Zvezdochka", are given in this report.

Observations and investigations, which have been conducted during the works under the Phase III of the project, show the preparedness of nuclear and radiation hazardous facilities of FSUE "EE "Zvezdochka" to EMS improvement and certification in accordance with COST R 14001-2007 requirements. These conclusions were drawn after examination of approaches to solving of environmental problems arisen from facility day-to-day activities. The requirements of normative and legal documents, including those related to environment contamination, are fulfilled in full measure. There are the programs on environmental safety improvement; training and examination systems that include environmental subjects are arranged; documentation maintenance system is sufficiently efficacious. And another important condition is that the management of FSUE "EE "Zvezdochka" is ready to provide the highest possible support for EMS implementation.

Thus, it is recommended at the first stage to include nuclear and radiation hazardous facilities of FSUE "EE "Zvezdochka" to EMS scope. In the case of positive results, EMS scope can be extended over the other facility's subdivisions. In developing the plans on EMS improvement and certification in accordance with COST R 14001-2007 requirements, it is necessary to take into account that these works require qualified scientific and methodical support. It is connected mainly with risk assessment during operation of any hazardous production facility. According to COST R 14001-2007 requirements, hazard identification and risk assessment are two necessary prerequisites for development of management plans on environmentally safe conditions of the works.

Conclusion

The final report on risk assessment at CUF of FSUE "EE "Zvezdochka" was prepared at stage 8. The report includes a brief description of the studied facility, the performed works and the results received in process of carrying out the project, as well as the recommendations. The more detailed information may be found in the reports on stages 4-6, prepared according to the PMP for FSUE "EE "Zvezdochka".

The executed analysis of accident risks in management of SNF at CUF shows that the facility has a high level of safety. The main objective of the activities should be upkeeping the current level of safety and gradual risk reduction, which can be done in the framework of annual safety assurance programs.

Attachment list

- #1 Abbreviations list
- #2 Characteristics of the safety-critical equipment
- #3 References

Abbreviations list

(Attachment 1)

NS	– Nuclear Submarine
CUF	– Coastal Unloading Facility
HI VNIPIET	– Head Institute "All-Russian Research and Design Institute for Power Technology", St-Petersburg
INES	– International Nuclear Events Scale
CBSE	– Construction Bureau of Special Engineering, St-Petersburg
MCC	– Metal-concrete container
EE	– Engineering Enterprise
MDE	– Maximum Design-basis Earthquake
RDTB	– Research and Development Technical Bureau
SPA CBTI	– Scientific Production Association Central Boiler and Turbine Institute, St-Petersburg
SFA	– Spent Fuel Assembly
SNF	– Spent Nuclear Fuel
PMP	– Project Management Plan
MTE	– Maintenance Technical Enterprise
CA	– Control Area
TK	– Transport container
TUK	– Transport package
DSS	– Department of State Supervision
FSUE	– Federal State Unitary Enterprise
NRS	– Nuclear and Radiation Safety
NRHF	– Nuclear and Radiation Hazardous Facility
NPU	– Nuclear Propulsion Unit

Characteristics of the safety-critical equipment

(Attachment 2)

The current section gives summarized description of the equipment used for transport and technological operations on management of SNF at coastal unloading facility of FSUE "EE "Zvezdochka".

Portal Crane

Transportation of radiation-protected package TUK-108/1 and container *sb.02 OK-300 PB* is carried out by the portal crane KPM 80/32 with 80 ton capacity

Transport package TUK-18

Transport package TUK-18 is designed to provide safe transportation of irradiated FA by motor, railroad and sea transport within the territory of the Russian Federation.

The container is operated in accordance with the following technical documents of the design and manufacturing organizations:

"Technological regulations for loading SFA into the protected container TK-18 and management of TUK-18 package within the territory of SEE "Zvezdochka", HI VNIPIET inv. No. 98-01487, 1998.

TK-18 container. Configuration and operation manual. DB of Izhora Plant. 1051.02.00.000 TO, 1989.

Shrouds. Configuration and operation manual. DB of Izhora Plant. 1051.36.00.000 TO, 1989.

Technical Report. Analysis of the strength and heating of naval TUK MCC in case of accidents during SNF management within the territory of temporary SNF transfer locations at MTE "Atomflot" and facility "09", Severodvinsk, FSUE CBSE, 2000.

Technical Report. "Additional analysis of safety of TUK-108/1 management at the accumulation pad for temporary storage of containers loaded with naval SNF at MTE "Atomflot". FSUE CBSE, 2000.

Transport radiation-protected package TUK-18 includes the transport radiation-protected container TK-18, a set of "ChT" shrouds (with a capacity to hold three, five, or seven spent FA depending on the type).

TK-18 transport container

Transport radiation-protected container TK-18 is designed for assorted placement, storage and transportation of SFA in seven "ChT" type or 24M shrouds, which are loaded into the removable part of the container.

The container consists of the shell, the removable part and the lid. The container shell is a thick-walled vessel made of corrosion-resistant steel. Two pivots for hooking the container to the cross-arm are located in the upper part of the shell. The container is equipped with damping elements: cones, teeth, ribs. The medium ring with twenty welded support ribs is used as a supporting platform when the container is loaded into the container carriage TK-VG-18 (TK-VG-18A). Three medium lengthwise ribs are welded uniformly every 120° between the medium and lower rings. Six lengthwise ribs with 40 mm diameter holes for slings used to move the container are welded to the external surface of the container between the lower ring and the supporting ring.

The lid is a welded element with damping ribs welded to the upper and ribs with holes for remote fastening of the lid with the cross-arm. Two rubber packings are located at the lower surface of the lid with a through hole between them used for container airtightness monitoring. In transport position the hole is closed by a plug with copper lining. The lid is fixed to the container shell with 24 bolts.

The removable part is used for assorted location of the shrouds. The welded structure of the removable part includes a base with four sockets for shrouds, the central tube and six supporting elements and diaphragms. A tube for extraction of water from the container is welded inside one of the supporting elements. The design of the removable part ensures fixed position of the shrouds during transport and technological operations with the container.

Specifications of TK-18 container are given in table 1.

Table P2.1. Specifications of TK-18 container

Parameter	Value
Container height, mm	4582
Outer diameter, mm	1405
Wall thickness, mm	315
Bottom thickness, mm	250
Lid thickness, mm	144
Container capacity, shrouds	7
Weight of empty container, kg	37470
Material of the shell, lid, supports, pivots, ribs	corrosion-resistant steel
Material of the removable part	corrosion-resistant steel

TK-18 container fully corresponds to the requirements of Russian standards and to IAEA rules for safe transportation of radioactive materials (1985). The container provides safe transportation of SFA shrouds both in regular and emergency conditions. Equivalent dose rate at

any location on the outside surface of the container does not exceed 2 mSv/hour in normal transportation conditions.

Mechanical impacts caused by fall and external thermal impact are considered as design-basis accidents in the technical documentation.

According to the design data, transport container TK-18 is capable of retaining integrity in case of free fall on a rigid foundation from the height of 9.0 m. In case of such impact the container retains strength and airtightness, while the release of activity from the inner cavity corresponds to the requirements of it. 2.3.6.b of OPBZ-83 [7].

Additional strength calculations [8] for fall of TK-18 from the height of 14.5 m onto ship deck with subsequent hit of the base (lower) ring of the container on the hard bottom of the sea demonstrated that the container does not lose airtightness and the release of activity from the inner cavity corresponds to the requirements of it. 2.3.6.b of OPBZ-83 [7]. Total height of fall of TK-18 container in the calculations was 26.8 m.

Additional research carried out for assessment of the protective properties of the container in case of fall from beyond design-basis heights are given in [9]. The calculations showed that:

In case of fall of transport package from the height of $17 \text{ m} \leq H \leq 30 \text{ m}$ onto a hard surface the container shell remains intact;

The integrity of the inner lid and the bolts used for its fixing is guaranteed for the case of fall of the transportation package from the heights 17 m and 30 m onto a hard surface. The joint is not opened.

Thermal calculation of TUK-108/1 [2] showed that in accordance with the requirements of OPBZ-83 [7] the TUK-108/1 package prepared for transportation may remain in the seat of fire (flame temperature of 800°C) for 30 minutes. The maximum temperature of the fuel claddings of the most heated SFA does not exceed the allowed values. The calculated temperature of metal reaches $328 \div 360^\circ\text{C}$ near the packing of the outer lid and 160°C at the inner lid.

Additional studies carried out by the Developer of rubber elements of transport packages, given in report [10] demonstrated that the upper temperature limits for the rubber packing is:

in normal operation conditions - 115°C ;

in emergency mode - 220°C (for a short period of time);

These data were used in report [11] to demonstrate that in the case of a design-basis accident, when TUK-108/1 is located in the seat of fire (flame temperature 800°C) for 30 minutes, the first (internal) airtight circuit remains functional, while the loss of the contents from TUK-108/1 package does not exceed the allowed values.

SFA shrouds

The shrouds are used for regular placement of SFA.

"ChT" type shroud is a welded structure consisting of tube block and a plug. The tube block is welded metal structure made of tubes welded to the shell and lower grate. Spacer grids are installed along the height of the tube block. The bottom is welded to the lower grid. A tube with an outlet leading to the shroud shell is welded into the lower grate for removing of water from the shroud. The plug is used to seal the internal cavity of the shroud and is made of a lid with rubber packing and a welded case with a gripping device. The gripping device is used to hook and move the shroud. The shroud is made of corrosion-resistant steel.

Type 24M shrouds are not currently used at "EE "Zvezdochka".

Reloading protective container sb. 02 OK-300 PB

The reloading container is used for unloading of SFA from the NS reactors and loading assemblies into ChT type shrouds. The container is shown in figure P2.1.

The shell of the container is a welded structure including an internal channel with a diameter of 80 mm and an external cylindrical sidewall filled with lead. The conical part and the foundation are welded to the sidewall. Pivots are welded to the external surface of the container to allow its transportation by crane and cross-arm. A winch is installed in the upper part of the shell via tube adapter. The winch is used for raising and lowering SFA using actuator handle. The container weight is 9000 kg.

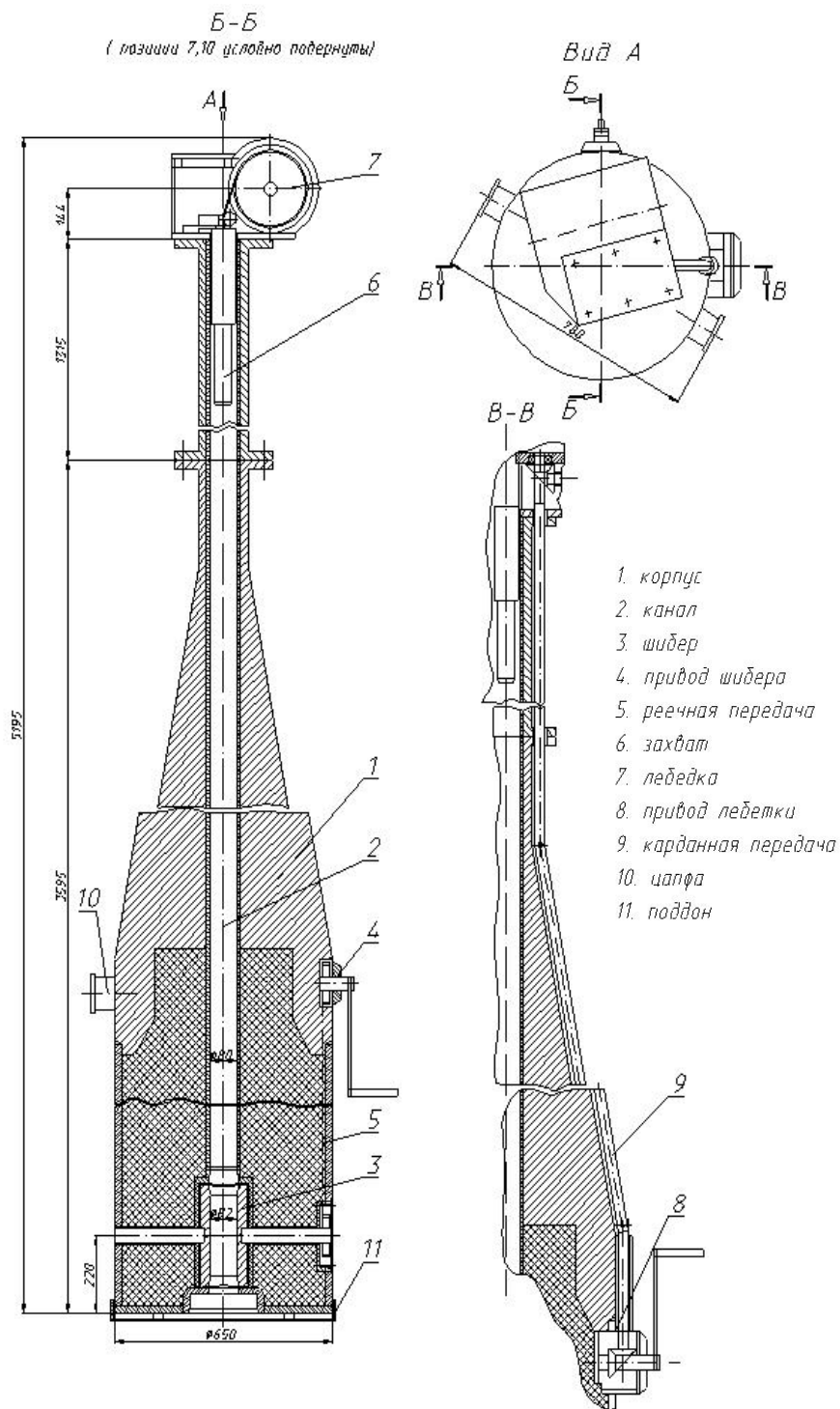


Figure P2.1. Reloading container (Positions 7, 10 are shown as turned)

Guiding Device

The guiding device is designed to aim and orient the reloading container with shroud sockets in the removable part of the protected TK-18 container in process of its loading with SFA and to ensure biological protection of the personnel in process of this operation. Specifications of the guiding device are given in table P2.2.

Table P2.2. Specifications of the guiding device

Parameter	Value
Weight of the guiding device, kg	8300
Biological protection thickness, mm	at least 325
Allowed load on the guiding device, kg	15000
Material of the main elements	corrosion-resistant steel

Guiding device cross-arm

The cross-arm is used for transportation of the guiding device of the protective container TK-18 or the guiding device support using load-lifting crane. The load-hooking elements of the cross-arm are equipped with latches preventing its accidental unhooking with the guiding device. Specifications of the guiding device cross-arm are given in table P2.3.

Table P2.3. Specifications of the cross-arm

Parameter	Value
Weight, kg	157
Capacity, t	10
Operating temperature range of the cross-arm	- 20 ⁰ C – + 40 ⁰ C

Monitoring and maintenance of the equipment

All equipment of the SNF management system undergoes periodic checks throughout its service life and additional checks after repairs. The scope and timing of the maintenance, tests and repair of load-lifting cranes and removable load-hooking equipment is determined by [1], and operating instructions prepared by the manufacturers of such equipment.

Additional tests and checks may be carried out if required by State Supervision Agencies.

The types and results of the carried out works are recorded in maintenance logs.

Before the start of the works the facility should carry out visual inspection, verification of completeness and functionality of all equipment used in transport and technological operations. The results of the carried out works are recorded in operations log and presented to the inspection of DSS NRS MoD RF for issue of a permit for performance of this type of works.

References

(Attachment 3)

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