Bellona Working Paper

Nuclear Andreyeva Bay

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Comments to this report are welcomed.

Abbriviations and terms

SNF —	Spent nuclear fuel
Rosatom —	Russian State Nuclear Energy Corporation
SevRAO —	Rosatom's subsidiary on the Kola Peninsula
SFA —	Spent fuel assembly
Mayak —	Spent fuel reprocessing plant in Sourthen Ural, Russia
Minatom —	Ministry of Atomic Energy
BTB 569 —	Military identification number for Andreyeva Bay
SRW —	Solid radioactive waste.

Contents

Introduction

In 1995, Bellona compiled a report entitled “The Russian Northern Fleet: Sources of Radioactive Contamination.” With this report, Bellona was first organisation of any kind to make public any data pertaining to the environmental conditions at the onshore technical base at Andreyeva Bay, the Northern Fleet’s former naval base on the Kola Peninsula and a largest site of storage of radioactive waste and spent nuclear fuel (SNF) in Europe. At the time, all facts relating to the technical base at Andreyeva Bay were classified and the information contained in Bellona’s report was not entirely without errors. Despite the inaccuracies, it was already clear 14 years ago that Andreyeva Bay was a time bomb and the detonator was ticking. Yet Bellona’s report came as a complete surprise even to then-governor of the Murmansk region, Yevgeny Komarov. Initial efforts to ensure safety at the storage site were impeded by the fact that the base was within the jurisdiction of the Russian Navy and absolutely no access to the base was allowed to civilian personnel. Still, the government of the Russian Federation acknowledged the importance of the problems accumulated at the Andreyeva Bay site and understood the dangers of the situation. In its Decree No. 518 of May 28th, 1998, the government ordered that the former onshore technical base of the Russian Navy undergo environmental rehabilitation.

Five years after Bellona’s report came out, and two years after the 1998 decree, the Russian government issued yet another document – Directive No. 220-p of February 9th, 2000. Under this directive, Andreyeva Bay was transferred into the purview of the then-Ministry of Atomic Energy (Minatom), later transformed into the Federal Agency for Atomic Energy (Rosatom). Today Rosatom is State Nuclear Enegy Corporation. A special structure was formed to implement preparatory and practical works on the sites of onshore technical bases. The new state-owned structure, dubbed the Federal State Unitary Enterprise “Northern Enterprise for the Management of Radioactive Waste,” or SevRAO, was headquartered in Murmansk and has a branch, called SevRAO Branch 1, in the closed administrative territory of the town of Zaozersk, which carries out environmental rehabilitation efforts at Andreyeva Bay. Andreyeva Bay was opened for access by foreign donors. Several nations – including Great Britain, Norway and Sweden –take part in the environmental rehabilitation project to take place at the former naval base.

In this document, Bellona will present the most detailed description of the accident that took place in Andreyeva Bay back in the 1980s. Bellona will also provide up to date analysis of the environmental situation at Andreyeva Bay at the present time, outline its position regarding the technical, technological and economic decisions made in relation to the nuclear waste storage site, and give its assessment of what has been done to enhance safety at the site in the past decades.

Chapter 1

1. The Andreyeva Bay accident

Storage of spent nuclear fuel in Andreyeva Bay

The onshore maintenance base in Andreyeva Bay was built and put into operation in 1961 through 1963. A pool-type facility dubbed Building 5 was built at BTB 569 to store spent nuclear fuel. The first order of the construction project was completed in 1962, and the second one in 1973.

The storage building, just like all other facilities on the territory of BTB 569, was being erected by conscripts of a military construction battalion. It should be kept in mind that in the USSR, the common practice for manning construction battalions was drafting soldiers from the republics of Central Asia and Transcaucasia, mostly uneducated boys who did not speak a good Russian. They were not considered to be trusted enough to handle any weapons but spades or crowbars and were forcibly sent to labor in the severest and most hazardous conditions found in places like Russia's north. The quality of constructions they were made to build was terrible.

In late 1989, the erstwhile functions of the onshore technical base that included submarine maintenance and collection for storage of spent nuclear fuel and radioactive waste were de facto discontinued. Only certain isolated tasks were still performed that were required by attending to the SNF and radioactive waste in storage. And throughout the period of between 1990 and 1997, Tank 2B was once used – to load 60 to 80 casks with SNF removed from floating support vessels and to unload the same amount to ship off for reprocessing to the chemical combine Mayak[1] in the Urals.

In a May 28, 1998 document by the Government of the Russian Federation, Decree No. 518, environmental remediation of the former naval base BTB 569 was finally given a priority. By Directive No. 220-r issued by the Government of the Russian Federation on February 9, 2000, the naval base in Andreyeva Bay was transferred into the purview of the then Ministry of Atomic Energy – now the state corporation Rosatom – to initiate a series of ecological rehabilitation measures. A new structure was formed in Murmansk to bring these measures to fulfillment – the Federal State Unitary Enterprise, Northern Enterprise for Radioactive Waste Management, or, simply, SevRAO. A SevRAO branch also opened in the closed administrative territorial entity[2] of the town of Zaozyorsk, located in the Bay of Zapadnaya Litsa, to handle operations on the grounds of BTB 569 in the nearby Andreyeva Bay.

Design of Buiding 5 SNF storage facility

Design-wise, the structure of the SNF storage facility in Building 5 consisted of two rectangular concrete chambers, or pools, with walls lined with steel on the inside. The pools were 60 meters long, three meters wide, and six meters deep, each pool with a total capacity of 1,000 cubic meters. Overall, the building was around 70 meters long and 18 meters tall. The water-holding capacity of the pool of Construction Phase 1[3], in the right- and left-hand sections, was around 600 cubic meters, or 600 tons. The pool of Construction Phase 2, in the right- and left-hand sections, could hold around 1,400 cubic meters of water, or 1,400 tons.

The facility's design storage capacity was around 2,000 casks. In later years, as spacing between the casks in the first pool was reduced to allow for more compact arrangement of casks with SNF, the building's storage capacity was increased to 2,550 casks (around 500 and 2,000 casks in the pools No. 1 and No. 2, respectively).

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[1] Mayak is a nuclear fuel reprocessing plant located near the town of Kyshtym, in Ozersk in the Ural region of Chelyabinsk. It is reputed to be the worst contaminated site on the planet, partly due to the extremely hazardous operating conditions and partly owing to a number of various accidents at the plant – most notably, the terrible radiation accident in 1957, also known as the Kyshtym disaster. In 1957, a failure of the cooling system for a tank storing dozens of thousands of tons of dissolved nuclear waste resulted in a non-nuclear explosion, followed by a release of 7.4×10^{17} becquerels' worth of radioactivity. At least 200 people died of radiation sickness, 10,000 people were evacuated from their homes, and 470,000 people were exposed to radiation. Radiation exposure remains a severe health hazard for those still living in the area, with reported high rates of cancer incidence and congenital disorders being among most common of afflictions. – Translator.

[2] Closed administrative territorial entities (or ZATOs, in Russian), part of the USSR's atomic-drive legacy, are a kind of "reservations" created for the country's scientific community by the Soviet top nuclear authority in the mid-20th century to conduct research and experiments deemed highly sensitive or classified. There are 42 such cities spread across Russia with a combined population of over two million; most of these locations are known by combinations of a name and a digit, such as, for example, Krasnoyarsk-66. – Translator.

[3] It is common for construction projects in Russia to be divided into planned phases, or stages – usually, two – developed one after the other to a level sufficient for each completed part of the site to be used for independent operation. When the last stage of construction is done, the project is considered concluded and, in the case of industrial sites, full design capacity or output reached. – Translator.

The spent nuclear fuel was stored at the site in casks, each holding five or seven spent fuel assemblies and placed under a protective layer of water – using the so-called wet storage method. With the SNF in it, each cask weighed around 350 kilograms.

The cantilevers from which the casks were hanging protruded over the water surface. The casks were held underwater with the help of heavy chains, fastened to the cantilevers in a particular geometrical grid pattern, at a specified spacing that provided for nuclear safety by ensuring that a spontaneous nuclear chain reaction would not take place in the pools.

All operations involving the casks were to be performed underwater. Water filled both the pool spaces and the casks with SNF in them. According to design stipulations, no contact was to occur between the cooling water of the pools and the water inside the casks with spent fuel assemblies. The protective water layer – from water surface down to the fuel-holding sections of the SFAs – was four meters thick, which, in the designers' projections, was to protect the personnel from gamma radiation and disperse the heat emitted by the SNF in storage.

A chemical water purification complex, after it was taken online, was supposed to help manage water quality and the levels of various contaminants. A pipeline system had been put together to connect the purification complex and other BTB 569 facilities. The complex was housed in a huge structure as tall as a six-story residential building. It comprised three tanks that were later retrofitted to be used as dry storage blocks. The complex was never, however, put into operation as a chemical water purification facility. At first, construction works were put on hold, then the facility was dismantled and, finally, ransacked, it fell into oblivion. The actual building housing the complex was used as a sanitary decontamination station during cleanup operations after the accident in Building 5. The quality of water in the storage pools remained under sporadic supervision, if any. Every now and then, the water was decontaminated with the help of portable purification systems.

The very design of Building 5, as well as that of the various equipment used to manage the storage of SNF in the pools, were far from perfect. Design defects resulted in radioactive contamination of the building, the surrounding territory, and the personnel working in the storage facility.

Design shortcomings which led to the accident

The designers thought that after a spent fuel assembly was loaded into a storage cask, it would still emit intense levels of decay heat, which would need to be removed. This is why the casks themselves were made of 12Kh18N10T-grade[4] steel and were manufactured in such a way as to allow for water to be poured inside to absorb decay heat from the SNF. The lower part of the cask had an opening covered by a red-copper diaphragm. Before shipping an SNF cask off to the chemical combine Mayak for reprocessing, Building 5 personnel would puncture this red-copper diaphragm with a sort of a special hole punch. After the perforation, the highly radioactive water contained in the cask would be drained off in that working area where the operation was performed. There was no other way to do this. Some of the fuel rods in the casks had been exposed to loss of seal. It goes without saying that every time after perforating the red-copper diaphragm of an SNF cask, the working station had to be decontaminated. But complete decontamination was impossible. It was done using a simple detergent mixed with water and an ordinary cleaning brush, but once they got onto a metal surface, the radioactive substances would penetrate deep into its crevices and scrubbing them out was a lost cause. This is why there were huge levels of background radiation at the working station, reaching sometimes 15 to 20 roentgen per hour.

There were other design and technological deficiencies. These are the most important of them:

- There was a place in the storage facility, a section of the protective slab that covered the pools, which called a "loading plate" – or simply, the "working station." The screw-jack bearing of the loading plate was invariably out of order. The bearing was this contrivance that helped retain SNF casks in a vertical position so that they could be unloaded from the so-called "primary" containers – containers used to hold SNF casks immediately after their removal from the floating technical maintenance facility, by which they had been delivered to Andreyeva Bay – before being placed into a pool compartment. Because the screw-jack bearing did not work, it was a very frequent occurrence that an SNF cask would simply slip off the working station and tumble under the protective slab, making it impossible to mount the next SNF cask onto the working station. There were no other devices to keep an SNF cask upright for unloading and prevent it from falling down.
- The bottom suspension brackets, on which SNF casks rested underwater, had to have a very reliable design in order to stop a cask from falling over under a dynamic strain. The brackets failed to meet

[4] Or AISI 321 in Western classification, a general-purpose brand of stainless steel. Areas of application include aircraft exhaust stacks and manifolds, chemical processing equipment, welding equipment, jet engine parts etc. – Translator.

these requirements. It took the slightest shove to the cantilevers or the loading plate for SNF casks to fall off the brackets to the bottom of the pool.

- Save for the home-made technology in use, the SNF storage building was not supplied with any kind of equipment to perforate the red-copper diaphragms of the lower ends of the SNF casks and to drain the radioactive water inside the casks into special containers – which is why the water would normally be drained back into the pool.
- The on-site water decontamination complex built for the SNF storage facility was not available, and as a result, the water in the pools – especially, in the left-hand one – was always highly radioactive. The mobile purification systems that the workers had to contend with were not too effective. Worse than that, these systems, parked near the working station, would themselves serve as powerful gamma radiation sources and they had to be shieled with lead sheets to avoid exposure.
- The designers of the SNF storage facility were wrong in thinking that the decay radiation in the pools would be strong enough to prevent the water from freezing over in the winter. This mistake was the reason why the pools had to be treated with hot steam to keep them warm enough during wintertime, which, in turn, led to a spread of radiation into the environment.
- The storage facility did not have any special containers to use for the radioactive water that had to be disposed of each time after the facility was cleaned. The water would simply be dumped outside on the facility's territory.
- The design of the primary containers, into which SNF, still warm, was reloaded from the holds of transport ships after delivery to the bay, also left much to be desired. Thick clouds of radioactive steam would escape from the containers' open narrow upper ends and flow over the territory.
- No technology had been developed to keep track of the spent nuclear fuel assemblies what compromised later the safety.

SNF transportation from the pier and to the storage facility in Building 5

For the transportation of SNF from the base's pier to Building 5, the following system had been developed: Project 326 (326M), later 2020, floating technical maintenance facilities – or simply, the support vessels that unloaded SNF off nuclear-powered submarine and icebreaker reactors and carried them to SNF storage locations – delivered spent nuclear fuel assemblies to Andreyeva Bay, to the so-called permanent technological pier. An eighteen-wheeler put together from BelAZ and KrAZ[5] trucks transported the primary container to the pier. With the help of the support vessel's shipboard crane, the container was hoisted off the rig and placed on top of the vessel's storage hold, where a cask with an SFA was loaded into it. Once loaded, the container was moved back onto the combination rig and hauled off to the unloading site at Building 5. The transportation route was approximately 350 meters long. The container was then transferred from the combination rig into Building 5 in an area called the "transport corridor." A 15-ton crane lifted the container and placed it into a special cradle, where it was relieved of its SFA load. Using chain suspensions and a one-ton crane crab, the cask was then moved underwater through the storage facility's operations hall and secured onto a cantilever in its storage spot.

This was a highly unreliable technology. Using a hook and a fickle suspension, the cask's upper end had to be fastened to its chain. Then, suspended by the chain, the SNF-carrying cask was being hauled by the crane crab along a narrow lane between the cantilevers. As little as one accidental bang made by the rocking chain at a cantilever led to the cask breaking loose from the suspension and tumbling down to the floor of the pool. The eventual result of that was the highly dangerous heaps of casks with nuclear spent fuel piled up at the bottom.

Such a transportation system was used to move SNF into storage in Building 5 between 1964 and 1982.

The accident in SNF storage facility

The first official announcement

The very first information about the accident in the SNF storage facility in Andreyeva Bay was made public by Bellona in March 1993 through the Norwegian national newspaper *Aftenposten*.

An official acknowledgement of the accident came a month later in a report prepared by a governmental commission investigating the disposal of radioactive waste at sea – a group headed by the prominent Russian environmentalist Alexei Yablokov.

A cleanup operation followed, which took seven years – between 1982 and 1989.

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5 BelAZ is a Belarusian manufacturer of haulage and earthmoving equipment based in Zhodino. The heavy-duty off-road KrAZ rigs are produced by the Kremenchug-based civil and military vehicle manufacturer AutoKrAZ Holding Company in the Ukraine. – Translator.

No conclusive analysis of the accident's consequences has ever been attempted by the authorities and, therefore, none has been made available for public access.

Heaps of SNF casks that fell to the bottom of the left-hand storage pool in Building 5 (Photo: Bellona archive).

Accident timeline

February 1982: A leak was discovered in the right-hand pool of the storage facility. In order to eliminate leakage, the chief of staff at the base proposed to pour 20 bags' worth of flour into the cracks in the pool through which radioactive water was seeping, thus "plugging" it with flour dough. This, naturally, did not yield the result that was hoped for and the leak continued. Maintenance personnel then found that ice was building up on the outer wall of the right wing of the building. A calculated guess was made that the pool water was leaking at a rate of about 30 liters per 24 hours. A working group comprising naval experts and the storage facility designers was put together to investigate the causes of the leak and suggest possible solutions. The overall conclusion was that the leak had been caused by damage in the metal siding that the pool walls were clad with.

By April 1982, the situation in the leaking pool had aggravated. Total leakage now amounted to 150 liters per 24 hours; levels of background gamma radiation had reached 1.5 roentgen per hour both in the area around the ice layer on the building's outer wall and in the storage facility's basement; sampling of the soil in the basement and of water taken from a nearby brook showed radiation concentration levels of $2x10^{-2}$ curies per liter and $2x10^{-4}$ curies per liter, respectively.

August 1982: Following a suggestion forwarded by one of the building's designers, workers started coating the basement of the storage facility with concrete. Around 600 cubic meters of concrete was altogether poured into the basement. That, however, had no effect on the leakage.

In the end of September 1982, leakage from the damaged right-wing pool increased drastically, reaching a catastrophic rate of 30 tons per 24 hours. This brought a very real risk of the top ends of spent nuclear fuel assemblies losing the protective layer of cooling water. The bare SFAs presented a tangible threat of overexposure for the personnel and of a radioactive contamination accident for the entire bay area adjacent to the base, as well as the estuary of the Zapadnaya Litsa river. In order to contain an imminent spread of gamma radiation, a suggestion was made to blanket the right-wing pool with slabs of iron, lead, and concrete, and later move the SFAs into dry storage.

On October 5, 1982, Northern Fleet Commander, Admiral Arkady Mikhailovsky approved the first order of response measures that included:

- Bringing to completion the iron-lead-concrete shield over the right-wing pool;
- Taking into use a supplementary water purification system to decrease radiation levels in both cooling pools;
- Preparing the left-hand pool for total unloading;
- Laying additional pipelines for re-feeding and emergency drainage of the pools;

- Stepping up works to finish the first underground storage tank, Tank 3A, in order to have it ready for the reception of SFAs to be transported from the faulty wet-storage facility;
- Non-stop decontamination of the entire territory adjoining Building 5.

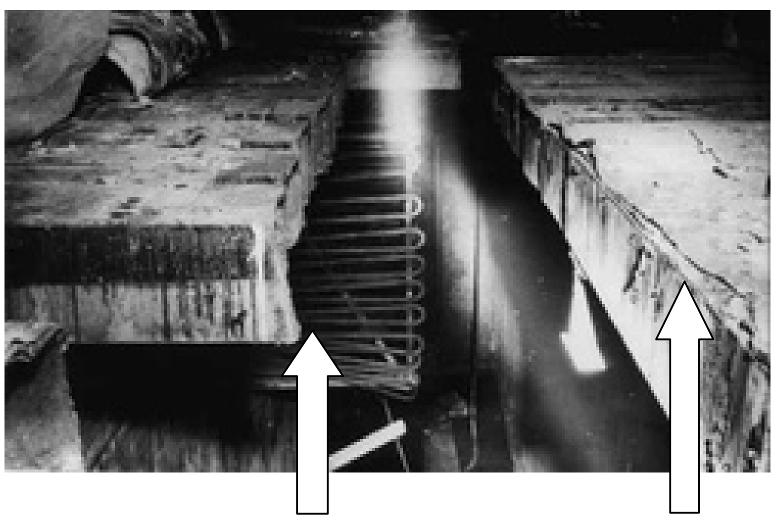
The plan, however, was not to be carried out in full. For instance, no sustained efforts were being made to decontaminate the area around Building 5; the standby pipelines needed to re-feed and emergency-drain the pools were never built.

November 1982: Construction works started to cover the right-hand pool with iron-lead-concrete slabs. As the slabs were being laid, a drop in the water level in the left-hand pool was discovered. In a week, the leakage from the left pool jumped up to a rate of 10 tons per 24 hours at a specific radioactivity of $3x10^{-4}$ curies per liter. Experts believe that such a dramatic loss of cooling water may have been caused by the construction works performed on the right-wing pool: Thousands of tons of bioprotective material were being placed on top of it. This must have resulted in the building's structure warping or sagging sideways under the strain and the left pool sustaining a loss of impermeability. It was sheer luck that the whole building did not collapse under the burden of the protective shield.

By December 1982, the condition of the foundering storage facility was as follows: The shield over the right-hand cooling pool had been completed; however, all of the cooling water, contaminated with radioactivity at a level of $5x10^{-5}$ curies per liter, had drained away from the pool and, carried by underground waters, gone into the bay. In the left-hand pool, the leak continued at an average rate of 3 tons per 24 hours; the specific radioactivity of the water was around $4x10^{-4}$ curies per liter. The cooling water held at a level of four meters and about 30 percent of the pool's surface was topped with slabs of concrete.

On February 14, 1983, a special commission enjoyed by the Ministry of Defense arrived at the base and confirmed a decision issued by the Navy's chief radiation authority to cease all operations in the storage facility except those needed for cleanup works. Since then, no SNF has been loaded into Building 5 for storage.

Between March 1983 and early September 1987, the left pool of the SNF storage facility was being emptied of its contents. Spent nuclear fuel previously in storage was unloaded and shipped off to Mayak – all but those SFAs that had fallen to the bottom of the pool and remained there untouched.



To provide access to the SNF casks that had fallen to the bottom of the left-wing SNF storage pool, the cantilevers over the pool were partially cut out by Seaman Recruit Tamtashev using a flame-cutter.

The loading plate – part of the protective slab stretching over the pool – where the so-called "working station" was arranged. The plate had an open narrow "passageway" through which an SNF cask suspended by a chain was moved along the pool under the water. Through an opening in the mid-section of the working station, the personnel were able to hoist an SNF cask out of the pool with the help of a lifting crane.

What caused the pool siding to crack?

There are several hypotheses explaining why the cracks had appeared in the pool siding:

1. Poor quality of the weld seams in the siding;
2. Shifts in the rock formation on which the building was erected that could have caused the weld seams to crack;
3. Drastic water temperature fluctuations that led the weld seams to sustain thermal stress and, consequently, disintegration.

In experts opinion, the latter may be the most accurate scenario for the following reasons. The storage facility pools had no water-heating system. Or rather, one had in fact been designed, but never installed. The consensus was that the decay heat from the SFAs that would be in storage in the pools for at least three years would be quite enough for the cooling water – filling a pool in an unheated space in a building operating in the Arctic conditions – to remain well above freezing level. The reality of working in the storage pools in Building 5 showed that when the temperature outdoors dropped lower than 15 degrees Celsius below zero, the pools would get covered with ice.

The lower the outside temperature was, the thicker the ice sheet was on the water surface. Once, when the ice built up as thick as 20 centimeters, it was decided to have the ice melted with steam. Technologically, this was easy: A hole was drilled in the ice and a pipe was lowered into it, through which steam was being pumped from the boiler house, day in and day out. This caused the temperature stress that destroyed the weld seams of the pool's metal siding and all the consequences that followed.

Recovery of the accident and its consequences

Detecting where exactly the cracks were in the metal siding required stepping down into the pool. This, however, was impossible, as many of the casks with SNF slipped off their suspensions and fell to the bottom of the pool. It was made the decision to isolate the right-wing pool with a protective lid. The pool was covered with a thick shield of lead, concrete slabs, and bags with sand. The heavy shield constrained the construction and apparently caused the left pool to start leaking. Up to 40 tons per 24 hours – were gushing out into the bay. Then the leak increased further, to between 350 and 400 tons per 24 hours.

The workers were forced to pump more water into the left pool, using fire hoses and water from the boiler house. Because water is the essential biological protection, it was necessary to always keep it in the pool at least at a minimal level in order to unload the SNF. If more water leaked out of the pool than was pumped into it, its level in the pool decreased and, consequently, levels of gamma radiation escalated and the personnel were exposed to substantial radiation doses. The works then had to be halted.

According to my estimates, altogether around 500,000 to 600,000 tons of highly radioactive water escaped into the Barents Sea from the left-wing cooling pool of Building 5 during the accident.

June 1983: The first underground dry storage tank, specially retrofitted to receive the SNF from the wet-storage facility, was taken online. In total, over 1,114 casks with no fewer than 7,500 spent fuel assemblies were unloaded from the left pool. The bulk of the SNF removed was shipped to the chemical combine Mayak for reprocessing. Twenty-five SNF casks that had sustained severe damage were spaced out loosely over the pool floor and remained there for a long time. The decision to space out loosely SNF over the pool was made in fear of spontaneous chain reaction. The operation to space SNF out was risky and required making of a special grabbing device. A part of the storage facility construction had to be removed with blow torches. A decision was made to pour boron into the pool, as boron absorbs neutrons. Some of the fuel casks were pulled out at that time. 25 fuel casks remained in the left-wing pool until the year 1989.

What was left of the radioactive water in the left-wing pool was drained into an underground tank using fire hoses. No one had checked the tank for watertightness. As the remaining water was pumped from the left pool into the underground tank, a large part of the Andreyeva Bay territory became contaminated with radioactive substances. The decontaminating procedures were non-existent in Andreyeva Bay. Therefore during the 30 years of operation the territory of Andreyeva Bay was at best cleaned with rain water.

The unloading of the part of the fuel casks did not solve the problem. There was no water in the pools, but some had been left in the casks and started, because of the low temperatures, to tear apart the metal shells of the casks and with them, the zirconium claddings of the fuel pins. This would mean that the fuel was falling through the cracks down on the pool floor. Numerous solutions were suggested, including freezing the entire building, complete with the basement and the rock it was standing on, with liquid nitrogen. After the freezing, the course of action involved pouring water into the damaged pools of Building 5 for biological protection and unloading the crumbling SNF from them using standard-mode unloading technologies.

Captain 1st Class Bulygin and his team proposed his own concept of solving the problem, namely, to unload the spent nuclear fuel without the protection of water, but using lead screens, lead-coated glass windows, and television cameras. The option proposed by Bulygin was accepted.

The work started in summer 1988 and was suspended in December. The reason for that was ineffective technology, which did not allow to unload the damaged fuel fast and safe. For instance, in the course of two shifts, the workers would be able to lift between five and seven casks, or 35 to 50 spent fuel assemblies, out of the damaged pool – and there were in total around 12,000 assemblies to retrieve. And while doing that, the personnel were exposed to substantial radiation doses. During the unloading operation around 1000 men were bought in. First, they were given radiation doses of 25 roentgen, then the dose was brought down to 10 roentgen per one go. They were never given their radiation exposure charts made out for active-service naval personnel on detached duty. No documents were ever issued to them upon discharge from naval service that would state that they had participated in the liquidation of a nuclear hazardous situation and radiation accident in Building 5 – therefore, they were never entitled to the protection of any social benefits that were later instituted.

So, a dead-end situation had thus presented itself. It became obvious that liquidating the nuclear hazard and radiation accident at Building 5 using the technology that had been agreed on would take years, and a huge number of men would have to sustain radiation exposure. Captain 1st Class Bulygin understood it, too. In late December 1988, the experimental SNF removal operation was ceased. A different method had to be found in order to enhance the labor efficiency of the task and decrease the risk of the men's overexposure to radiation.

The date when real, constructive work to eliminate this largest radiation accident started is effectively June 1, 1989.

It all went fast from there. Instead of 35 SFAs, it was possible to unload up to 375 spent nuclear fuel assemblies every 24 hours. Exposure doses went down dramatically for the liquidators, too. After retrieval, the damaged SNF was transported from Building 5 into dry storage tanks.

The transportation was done according to the following scheme: The KrAZ truck, which carried the container with defective SFAs from Building 5, pulled up at the dry storage blocks and the contents of the container was reloaded into dry storage cells using a crane. A dry storage cell was basically a rusty pipe 4 meters high and with a diameter of 400 or 275 millimeters. After loading, the top of a cell was covered with a lid, which provided no air- or watertightness. The casks with SNF were either severely deformed from banging so badly at the steel bottom of the pool or totally destroyed by ice. Sometimes, fuel was spilling out of the SFAs as they were being reloaded, emitting gamma radiation at levels ranging between 800 and 17,000 roentgen per hour. A seaman recruit would pick up the spilled fuel with an ordinary shovel and a brush and pour it into the rust-covered pipes of the dry storage blocks. Such loading technology was apparently creating the conditions where a local critical mass would accumulate in the pipes and lead to a spontaneous chain reaction – or a nuclear flash. Such cases were also observed in Building 5.

A protective screen was used to load Tanks 2A and 2B of the dry storage facility with SNF from Building 5. It turned out later that high levels of gamma radiation still led to severe exposure of the personnel hiding behind the shield as rays of radiation traveled around, reflected by the tank walls (Photo: Bellona archive).

Area contamination after SNF was unloaded from the storage facility

In 1989 all the SNF – 1500 fuel assemblies (including 25 assemblies at the bottom of the left pool) – were fully unloaded. At present, the wet storage facility is not in operation, but the building itself is in a highly precarious condition. No decontamination has been performed on the building. Examinations have revealed that there still are certain areas at the pool bottom that emit gamma radiation at levels as high as 40 roentgen per hour. This evidence suggests the presence of small scattered heaps of loose granules of spent nuclear fuel spilled out of damaged SFAs onto the pool floor. The pool was to be treated with a coat of self-solidifying preservative compounds, but in fact it never was. Experts categorize all of the interior structures of the building, complete with the equipment housed in it, as mid- and high-level radioactive waste. Proposals have been put forward to employ the building as a solid radioactive waste storage facility. However, these suggestions never amounted to any serious project work, and at the moment, no clarity – much less a definitive plan – exists as to whether the building will be kept for further use or destroyed completely.

Likewise, it still is a mystery where exactly hundreds of tons of radioactive water leaked from the damaged pools of the storage facility. Many believe the water seeped away into natural formations underground. No research has been undertaken to verify this theory. It is most likely that all the leaked water ended up in the bay.

The most disturbing of these facts is that after the emergency works ended at the facility and both pools of Building 5 were emptied of their spent nuclear fuel, all logs that kept track of the SFAs and their arrangement as they were relocated into dry storage were lost. No records remain of the number and condition of SNF in storage in Andreyeva Bay. Plans have surfaced to inventory the SFAs in dry storage blocks and map out their exact arrangement and location, but volunteers are yet to be found for the task since reconstructing these data is now beyond the bounds of practical feasibility. The uncertainty this creates is a highly negative factor impacting the nuclear and radiation safety of the site. The absence of data on the energy yield of these SFAs and the precise period of time they have been in storage makes it impossible to determine which conditions might ensure their nuclear and radiation safety, including how tenable is the risk that a spontaneous chain reaction will occur at the site.

Spontaneous (or self-sustaining) chain nuclear reaction: Theory and practice

The possibility of occurrence and development of a spontaneous chain reaction has been well corroborated by practical experience. Over the several decades that atomic energy has been applied in Russia and, formerly, in the USSR at various enterprises of the Soviet and Russian nuclear industry, at least 13 emergency situations involving the development of a spontaneous chain reaction have been documented by official records alone. The majority of these incidents took place at chemical and metallurgical plants while performing works with plutonium and highly enriched uranium. There were also several cases that demonstrated that sometimes "nuclear flashes" would occur in a laboratory environment. These were attributed to erroneous actions on the part of the personnel, who were thought to have created conditions allowing for nuclear criticality to occur while handling highly enriched materials.

Under normal conditions, highly enriched uranium is stored in such a way as to ensure subcriticality. For instance, in wet storage facilities, spent nuclear fuel assemblies in storage are arranged at a particular spacing. This is done because the process of nuclear fission is still in progress even in burnt-up fuel and new neutrons are being produced which, as they collide with other atomic particles, primarily, nuclei, may trigger the next fission event and so on.

The threshold at which a chain reaction occurs in fissile material – such as spent nuclear fuel – is called criticality. Arriving at a point of criticality is contingent on such factors as the density, geometry of shape (critical size), and the mass of the substance (critical mass). The critical mass of a fissionable material is heavily dependent on its composition, with variations of a dozen grams making a difference at very high levels of enrichment. The mass is critical when the neutron multiplication factor (**K**) equals 1. A supercritical mass is one where there is an increasing rate of fission, or where **K>1**. The neutron multiplication factor (**K)** depends heavily on the degree of enrichment of the fissile material, in this case, uranium 235. At an enrichment degree of 15 percent (in marine nuclear propulsion systems, the degree of enrichment in reactor cores is around 30 percent), a chain reaction is achievable with fast neutrons, i. e. without the use of a moderator, such as water. However, the probability of a fission chain reaction increases even more with the presence of water as a moderator, i.e. when highly enriched uranium – in this case, SNF – and water mix together. Water slows down the neutrons, damping their speed and energy, thus increasing the rate of neutron collisions and the number of new fission events.

Experience shows that provided all of the above requirements are met, there is a high probability of occurrence of a spontaneous chain reaction at sites similar to the storage facility in Andreyeva Bay, since it is quite possible to achieve supercriticality in fuel with a high degree of enrichment. For instance, by scooping up spilled spent nuclear fuel and pouring it into a storage cell, thus creating a critical mass (or particular density or geometry of shape).

The distinct nature of this process as it happens under such conditions is well-researched, too. Scientists at VNIIAES[6] have examined and simulated spontaneous chain reactions as they might occur in the conditions of nuclear fuel storage facilities at nuclear power plants and have assessed the scope of the concomitant streams of neutron and gamma radiation that occur during such events. It has been established that the process of a spontaneous chain reaction would be that of a short duration, as a "neutron burst."

The occurrence of such "bursts" has not been an uncommon experience at Soviet and Russian uranium-enrichment facilities and at the chemical combine Mayak. Practically all known cases of a self-sustained nuclear reaction took place at such sites. When a burst like this happens, it is accompanied by a heating-up effect, then the chain reaction dies out under the force of the negative temperature coefficient of reactivity. The intensity of this process depends on a range of factors – the amount of fuel in which fission reaction takes place, the geometrical parameters of the location where the nuclear reaction has started, how well sealed the shell of the container is where the reaction occurs, or whether a moderator, such as water, is present, etc.

Of course, there is no likelihood that the environment of a spent nuclear fuel storage facility would allow for the occurrence of an explosion similar to that which happens in an atomic bomb, since the design and engineering requirements for the blast of a nuclear bomb are simply absent under such conditions. However, a short-lived self-sustaining chain reaction, a nuclear flash, is still quite possible and may lead to the creation of streams of fission neutrons and instant gamma radiation, which aggravate substantially the radiological environment at the site.

The principles described above confirm the observations provided by liquidators in Andreyeva Bay.

Bellona has previously published a range of articles and papers where the probability of a spontaneous chain reaction occurring as a neutron burst in Andreyeva Bay has been acknowledged by a number of nuclear experts. In their assessments, the likelihood of this happening is sufficiently miniscule, estimated at 10^{-6}. One has to bear in mind, however, that when quantifying the probability of occurrence of this event or another, the final estimate is entirely dependent on the given initial criteria perceived as the primary point of reference. It is highly unlikely that these scientists, calculating the odds of a spontaneous chain reaction in Andreyeva Bay from their Moscow offices, could have seen or imagined the conditions under which spent nuclear fuel was being unloaded from the damaged storage facility. It is likewise impossible to predict now with a convincing accuracy the conditions under which this SNF will be further unloaded from the dry storage blocks and what actions the personnel will take while performing this work.

Things happen in life that no one could ever predict. For instance, who could have thought – or calculated, at least approximately, the likelihood – that two satellites, an American and a Russian one, would smash into each other in outer space, hundreds of kilometers above the Earth? Yet, it did happen[7]. We have to remember that.

Dry storage blocks

Following a suggestion forwarded by the Northern Fleet Technical Department, a project was developed to store spent nuclear fuel – including those fuel assemblies that were unloaded from the damaged pools of Building 5 – in deep tanks that had previously been constructed at the site and were intended for storage of liquid radioactive waste, but up to that point remained empty. The project, approved by the command of the Northern Fleet, was estimated at around 400,000 roubles, in 1982 figures.

The project design pivoted on the decision to modify the three unused tanks of the inoperative water decontamination complex – each with a holding capacity of 1,000 cubic meters – for storage of the relocated SNF. The storage technology chosen for this facility was that of a "dry" storage method. Initially, the intention was to keep the SNF there on a temporary basis – for around three or four years. The new storage facility project was developed by organizations working under the purview of what was then the Ministry of Atomic Energy. The plan was to launch capital construction works in 1984.

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6 This Russian acronym stands for the Moscow-based All-Russian Scientific Research Institute for Studies of Nuclear Power Plant Operation. Among the center's many functions are studies of the operation and maintenance of nuclear power plant equipment and systems, mathematical modeling of reactor processes, engineering operational training systems and simulators, conducting a variety of equipment tests, and working with radiation safety issues. – Translator.

7 For more on this incredible collision, which happened in February 2009, see, for instance, a CNN story at http://www.cnn.com/2009/TECH/02/12/us.russia.satellite.crash/index.html. – Translator.

It was by November 1982, however, that military construction units already started re-equipping the first tank of the dry storage facility in preparation for SNF relocation. Retrofitting the first tank, Tank 3A, took six months, and in June 1983, it was ready for use. The following tanks, Tanks 2A and 2B, were put into operation in 1985 and 1986, respectively. The first tank was modified to hold 900 casks with SNF, the other two had enough capacity for 1,200 casks each. A KPM-40 portal crane with a boom reach of 30 meters and a lifting capacity of 40 tons was assembled for loading and unloading operations. The site was also equipped with a sanitary decontamination and radiation monitoring station and a special ventilation system that provided air as a cooling agent to shield against radiation – much like water is used in wet storage facilities.

The dry storage tanks were used to store all of the SNF transferred from Building 5, as well as, starting in 1984, the spent nuclear fuel unloaded from submarine reactors as part of routine refueling operations.

Soldiers from a construction battalion arrived in Andreyeva Bay to start the modification works. The tanks, 18 meters in diameter and four meters deep, were equipped with four-meter rusty pipes, made of ordinary steel. The pipes, 400 millimeters in diameter, were standing upright at a particular interval from each other, in order to ensure nuclear safety, and forming a sort of a grid as they were welded into a reinforcement carcass. The space between them was filled with concrete. Each tank was thus equipped with around 1,000 pipes. Nobody, though, took any trouble to make sure that Tank 3A would be sheltered by at least some kind of a roof and provided with proper ventilation, complete with filters to clean the air from radioactive substances.

The roof over the tank was needed if only because the storage cells had to be protected from atmospheric precipitation. Tanks 2A and 2B were only covered by some sort of makeshift roofs, leaking like sieves, through which outside moisture – rain and snow – seeped into the cells holding SNF. To make that clear, the dry storage facility was in effect designed and built and put into operation under the open sky in Arctic conditions. Even before SNF from the faulty Building 5 was transferred into the dry storage tanks, the facility had already become the site of a radiation emergency. The rain, the snow, the meltwater that was dripping into the dry storage blocks, all became radioactive water collecting in the pipes. Later, as a cask with spent nuclear fuel was being placed into a pipe in the course of standard-mode loading operations, it would suddenly turn out that the pipe was half-filled with water. The radioactive cask would be loaded into the pipe nonetheless, and radioactive water would be pushed outside, overflowing the rim and spreading all over the dry storage block, adding to the background radiation levels.

There was a ventilation system built to clean the air in the storage blocks, but it was very primitive and permanently out of order.

To work inside this facility, it was required to wear respirator masks to protect our throats and lungs from breathing in radioactive substances in the air. But the masks were only effective if the outside temperature was above zero. Every time it got down to 15 degrees Celsius below zero, the cold would make the respirators stick like glue to our faces. As the makeshift roof over Tank 2A or Tank 2B, to load SNF which was still a long time away from exhausting its decay heat, was lifted up heavy plumes of radioactive steam would escape from the tanks. These fumes created a lot of troubles for the personal.

The dry storage pipes were drowned in rainwater, and SNF transferred from Building 5 was loaded straight into water at the new storage place. Most of the casks were bent due to the heavy blows they had sustained when they dropped to the pool bottom from a height of six meters, or because of the ice, and some had lost the lead plugs that were supposed to seal their top ends. Some casks had turned faulty because of some other problems. A crane was then used to lift the SNF casks from the transport container. If no fuel was spilling out of them and no broken bits of fuel assemblies with uranium composition fell out. The casks were loaded into storage tanks “as is”, without any regular lead protection, since all of the casks were damaged and it was impossible to handle them using standard equipment. Numerous times a bent SNF cask would not fit entirely into a storage cell, half of it sticking outward. It had to be lifted a 15-ton standard primary container with a crane and use it to prod the unruly cask carefully, forcing it into the storage cell with the container’s pressure. It also happened frequently that as a damaged SNF cask was hoisted up to be placed into a storage pipe, loose granules of spent nuclear fuel would spill right on the concrete fill of the tank.

Tank 3A was the first of the dry storage tanks that was put into operation. Not even so much as a semblance of a roof was built to cover the tank to protect it at least partially from rainwater or snow collecting in the storage cells. The pipes in this tank were filled very quickly with SNF shipped to the base by the Navy. After the tank was loaded to capacity, concrete slabs were placed on top of it for cover, but needless to say, they were not watertight. So, when the defective SFAs were transferred from Building 5 seven years later, in 1989, practically all of the pipes in Tank 3A were awash with rainwater.

The damaged SNF casks were loaded into the tank's cells, filled as they were with water, some only halfway and some to the brim. The water, heavily contaminated by then with radioactivity, was pushed out of the pipes as the SNF casks were being pushed in and streamed all over the concrete surface of the tank. The personnel on shift slopped through this water, getting exposed to awful doses of radiation and spreading this radioactive filth all over the place.

Tank 2B presented the same sorry picture. Though it did have some makeshift cover, still almost all the storage cells in it were filled with radioactive water. While the dry storage blocks were being designed and built in the tanks intended for liquid radioactive waste, the assumption was that they were all lined with stainless steel sheets, that is, that they were impermeable to water. A curious fact has just recently been discovered, though. It turns out that the bottoms of Tanks 3A and 2B have no steel siding, meaning that they are not watertight. This information is of critical significance for the case at hand, since these tanks hold most of the damaged spent nuclear fuel unloaded from Building 5. In essence, this SNF – zirconium-clad fuel assemblies torn apart by ice and spilling loose pieces of fuel composition – is being stored there open to contact with water and air.

The servicemen on active duty at the base, as well as their shift supervisors, were always exposed to severe doses or radiation and contamination with beta particles when they worked at the dry storage facility. There was no solid radioactive waste repository, so all of the radioactive rags were dumped at sea in metal containers or used to stuff the rusty pipes of the dry storage blocks.

The condition of the remaining parts of the casks is unknown because none of the casks with SNF in storage in the dry storage blocks have ever been moved from their cells since 1989. A few years back, there was an attempt to take one of the SNF casks out for an examination, using a KPM-40 crane with a lifting capacity of 40 tons for the necessary pulling effort. That effort, however, was not enough – the cask would not budge. Even in this "safest" tank, the lids that cover the storage pipes have rusted through so badly they have stuck to the pipes as if welded in, so, as information from those sources says, not even a screw jack with a thrust capacity of 500 kilograms could break the resistance of the bond created by the layer of rust between the cell's rim and the lid. It is simply impossible to unplug the pipe unless the lid is cut off. If we analyze the cartogram of the gamma field in the observed area of Tank 2A, we can see that levels of gamma radiation around the cells' lids are quite substantial, even though 20 years have passed since the SNF was loaded into this storage tank.

The cleanup operation undertaken to eliminate the nuclear hazard and the consequences of the radiation accident in Building 5 concluded on December 13, 1989.

The heaviest part of the burden of liquidating this radiation accident fell on the shoulders of over 1,000 young Soviet sailors, who the state denied any social protection or awards. They paid the highest price cleaning up the consequences of the accident in Building 5 – their own health.

Solid and liquid radioactive waste

Levels of contamination of the territory and environment of Andreyeva Bay with radioactive substances were enormous. There has never been and still is not any sheltered and properly equipped storage facility for solid radioactive waste at BTB 569.

The worst sources of this contamination were the dry storage blocks, Building 5, and the so-called Yard 3, where solid radioactive waste was stored. The Yard 3, standing uncovered and open, was located 200 meters from the bay in the southern part of the base. It was surrounded by barbwire, solid radioactive waste was piled up right under the open skies. It was as if this yard, extremely hazardous from the point of view of risk of contamination to the environment, was specifically designed and built at a significant elevation over the rest of the territory and its other sites. Any kind of contaminated equipment used for loading and unloading of reactor cores qualified as solid radioactive waste, as well as protection suits worn by sailors – and sometimes even new uniforms that became radioactive because of the dust storms that frequently blew over the territory of the base.

When liquidating the radiation accident in Building 5, it was used a new KrAZ truck. When those works were over, the rig – already nothing more than a heap of solid radioactive waste – was parked at Yard 3, and then, when an SRW repository was built, it was buried there. The SRW repository is a big crater filled with cement.

Table 1 Overview of the SRW stored in Andreyva Bay.

SRW type	Present storage mode	Storage site	Number
Nuclear submarine reactor control rods	Spent nuclear fuel casks	Open site	Around 5500
Filters from 1st and 3d cooling circuits of submarine reactors	Containers	Open site	306 containers
Reactor equipment	Containers	Open site	133 containers

Chapter 2

2. Remediation of Andreyeva Bay

A time of uncertainty

On December 13, 1989, the last of the spent nuclear fuel from Building 5 was moved into dry storage blocks.

Beginning in 1990, the onshore technical maintenance base in Andreyeva Bay started phasing out all operations involving the reception for storage of SNF unloaded from submarine reactors and shipping that SNF off to the reprocessing plant at Mayak. The main wet storage facility – Building 5 – was taken out of commission; using it for the purposes it had been built for was no longer possible. The new dry storage facility could only be used to accommodate the fuel that had by then been stored for a sufficiently long time in wet storage holds of the nuclear fleet's maintenance vessels and whose decay heat should have by then reduced significantly. Consequently, the value that BTB 569 held for the Northern Fleet as its main temporary SNF storage site was gradually diminishing. The last time a spent nuclear fuel shipment was transferred onto Andreyeva Bay grounds from a maintenance vessel and accepted for storage and further transportation to Mayak was in 1993. After that, the main activity still taking place in BTB 569 was receiving, and managing the storage of, radioactive waste. This was predominantly solid radioactive waste – radioactive metal – and the highly radioactive ion exchange sorbent generated during the replacement of filters in submarine reactors' primary cooling circuits. The fleet kept accumulating this radioactive waste as those submarines that were still in service needed refueling and the decommissioned ones needed to have spent nuclear fuel removed from their reactors.

The level of professional expertise among the personnel working in Andreyeva Bay was steadily decreasing. The workers were mainly engaged in routine maintenance chores, upkeep of the buildings and storage facilities, as well as operations involving the management of radioactive waste and fresh nuclear fuel, which was still in storage at the base, housed in Building 34. Gone were the specialists who used to oversee the storage of SNF and who took care of the radiation accident and the nuclear hazard in Building 5. Some of the subdivisions detached to Andreyeva Bay were still there – such as the Reactor Criticality Laboratory – but the lab was already working with other technical maintenance bases of the Northern Fleet and with the shipyards where fresh nuclear fuel was loaded into – or spent nuclear fuel removed from – submarine reactors.

It was at this juncture in Andreyeva Bay's history that another emergency occurred at BTB 569: A theft of two kilograms of highly enriched fresh nuclear fuel from Building 34. This incident, a first on the Northern Fleet's record, took place in 1993. The fuel, stored in Building 34 as fresh fuel assemblies, had been intended for loading into the reactors of Typhoon[8]-class nuclear submarines. It was purely by chance that the theft was even discovered.

The theft of uranium in Andreyeva Bay

Building 34 was used at Andreyeva Bay to take the delivery of, store, and ship off to the Navy new fuel for reactor cores – fresh fuel assemblies. This earth-sheltered structure stood a few meters away from the main road that traversed the territory of the base, not far from Building 50 and Yard 3. At present, this building is used as a warehouse for equipment owned by SevRAO.

The regular practice was that no more than six full new reactor fuel cores would be in storage in Building 34 at any given time. The fresh fuel bundles were delivered to the base by the fleet's maintenance vessels in cases holding five assemblies each. These cases were transferred from the support vessel they had arrived on into a KrAZ truck using a lifting crane. Because the truck was not furnished with the equipment necessary for safe transportation of cases with fresh nuclear fuel – and was thus essentially ill-equipped for the task – it was a frequent occurrence that the cases would fall out of the truck bed, namely off a height of over four meters, onto a hard reinforced concrete floor. Every time that happened, the situation warranted that the cases be opened and examined to check the fresh fuel bundles in them for any damage they may have sustained. In reality, though, it was almost never done – ostensibly to avoid breaking the factory seals on the cases. The truth was, however, that no one ever wanted to have to report these incidents to the upper ranks.

The reactor fuel was accepted for storage in cases bearing factory seals without ever checking the cases' contents – even though the cases held fresh fuel assemblies containing 36-percent-enriched

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8 Or Akula, in Soviet Navy classification.

uranium. No inventory was done even in such instances when the support vessel would deliver cases whose walls were deformed or factory seals damaged.

Once in Building 34, the cases were unloaded off the truck and grouped into batches, each equivalent to one reactor core load. In each batch, the cases with fresh fuel, standing upright, were tied together with wire so that they would not fall over. Building 34 could accommodate eight fresh fuel cores at a time at the most, but, as a rule, no more than six were stored there. According to nuclear safety procedures, the building had to be equipped with electrical heating. However, the fresh fuel storage facility used a steam heating system. There were frequent incidents when steam pipes would burst and the building would suffer partial flooding.

Overall, security was organized in such a way that this extremely sensitive nuclear materials site was basically left with no oversight at all.

Two people were arrested on July 29, 1993, who later admitted having stolen the 1.8 kilograms of enriched uranium 235 from Building 34. The suspects had intended to smuggle the uranium abroad and sell it there. Fortunately, the two stolen assemblies were immediately recovered, and the thieves apprehended. These two turned out to be sailor recruits who were directly involved in the operation of Building 34.

Before getting caught, they had managed to take apart one of the fuel assemblies. Because the sailors were not interested in the metal parts of the fuel assembly, but only in the uranium fuel, they had cut the fuel-containing section of the assembly from the suspension bracket used to fix the fuel assembly inside a fuel channel. A fuel assembly is a rather heavy object to carry around, and bulky, too, so the thieves needed to dismantle it also for the reason of "handling" it with better convenience later on. The dismantling operation itself is hard work, so they only had the time to deal with just one of the assemblies.

Bellona brings attention to Anreyeva Bay

The situation at BTB 569 in Andreyeva Bay was gradually deteriorating. The base's buildings and structures were rapidly aging and dilapidating under the rough influence of the severe northern climate. It soon became clear that the dry storage facility – something that had been built as a temporary solution until the situation with SNF storage could be resolved in three or four years – had morphed into a long-term headache for everyone involved. Brought into stark relief were the various engineering oversights and errors made at the stage of designing and building the dry storage blocks. The officials who had been making decisions regarding SNF storage at the base and who were responsible for them were gone, relinquishing authority over the matters and divesting themselves of any accountability for their actions. There was no one to take to task for what was happening. The army and the Navy were undergoing major cuts, lapsing into a state of total ruin and disarray. The Northern Fleet was removing submarines off active duty by the dozen, but it had no means, resources, or capacities to decommission them. Languishing at their piers were around a hundred submarines and surface ships taken out of operation and waiting forever to be decommissioned. Both the naval personnel and civilians working for the Navy had to struggle through salary delays that were sometimes as long as six months. It became quite obvious that under these circumstances, no funds would be coming to maintain the safety of SNF in storage in dry storage blocks, to say nothing of building a new storage facility. It was a time when international support programs had not yet been initiated in Russia's North and hardly anyone knew just how serious the dangers that had mounted at the Northern Fleet bases really were.

It was in this period – 1995 to 1996 – that Bellona charged itself with the task of bringing to light the dire situation that had developed in what by then had become the Russian[9] Navy, including its technical maintenance base in Andreyeva Bay. It was from Bellona's *The Russian Northern Fleet: Sources of Radioactive Contamination*, the so-called *Blue Report*, that the world found out for the first time about the nuclear and radiation risks accumulated at Russian naval sites. The report made waves both within the international community and among the authorities in Russia. The then-governor of Murmansk Region Yevgeny Komarov made an open statement in the press saying he had never suspected there were such dangerous sites in the region under his purview. A range of project initiatives followed immediately from Norway, which was extremely concerned about what was happening so close to its borders, and from other countries as well. These offers were not always met with a wholehearted welcome since the Navy was trying hard to keep its "secrets," including from its own superiors. The "secrets," however, were of the nature that would burst into the open no matter how well kept.

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9 Russia seceded from the Soviet Union in 1991, gaining sovereignty as the Russian Federation.

Beginning in late 1995 and through to 2000, Bellona was, unfortunately, in no position to tend consistently to the situation in Andreyeva Bay as it was fighting the Russian secret services in what became known as the Nikitin Case[10]. And it was, in our view, exactly during that period that a lot of opportunities were missed that could have changed the state of affairs in Andreyeva Bay.

In 1997, the Russian military reported that a strong radioactive leak had developed on the territory of Andreyeva Bay – a stream of contaminated water that started somewhere under Building 5 and flowed further into the bay of Zapadnaya Litsa. The military failed to detect the exact source of this leak, so a decision was made to divert its flow and then block it off completely. An offer came from the Norwegian authorities to finance this project. Its implementation, however, was impeded greatly by the reluctance of the Russian Ministry of Defense to give international experts any access to the sites in Andreyeva Bay. Despite these limitations, Norway agreed to fund the project, donating around $817,000 to the Russian partners so that the radioactive stream flowing from under the former SNF storage facility could be turned away from the bay and the emergency liquidated. The project was finished in 1999. All works had been performed by the Russian side; Norway received a project completion report, which consisted of a number of photographs.

Russian government starts turning attention to Andreyeva Bay

On 28 May, 1998, the Government of the Russian Federation issued Decree No. 518 titled "On measures of expediting the decommissioning of nuclear submarines and surface ships with nuclear propulsion systems taken out of operation by the Russian Navy, as well as environmental remediation of naval radiation-hazard sites." In line with this decree, the Ministry of Defense was to transfer to the Ministry of Atomic Energy all functions as the state contractor and coordinator of measures carried out within the program of comprehensive decommissioning of retired nuclear submarines and environmental rehabilitation of the Navy's radiation-hazard sites, including that in Andreyeva Bay.

Between 1998 and 2000, a variety of bureaucratic entities were created to implement the instructions specified in the decree, such as the Ministry of Atomic Energy's Department of Ecology and Decommissioning of Nuclear Sites, the Committee for the Conversion of Military Sites and Nuclear and Radiation Safety of Murmansk Region, etc. In February 2000, another document by the Government of the Russian Federation, Directive No. 220-r, authorized the creation of a specialized entity, the Federal State Unitary Enterprise Northern Enterprise for Radioactive Waste Management, or SevRAO, which started the process of official transfer of the onshore technical maintenance base in Andreyeva Bay (and another one, in Gremikha, which is the easternmost of the Northern Fleet naval bases on the Kola Peninsula) from the jurisdiction of the Navy into its own purview. All formalities this process entailed were finally concluded in 2001.

The years between 1998 and 2001 could be called a time of transition for Andreyeva Bay. Translating into practical reality, it is this "interesting" period when the old boss is not the boss anymore, and the new one is not the boss just yet – that is, no one, essentially, is in charge of anything or has to do anything. Beginning in 1993 and until 2001, no efforts were undertaken to solve the major task of removing the gigantic stockpiles of spent nuclear fuel from the SNF storage facility in Andreyeva Bay. Yet, as information available today shows, the situation with SNF in storage at the base was going from bad to worse with each passing day. It was apparently such an evident disaster that it could be seen with the naked eye, which is probably why Andreyeva Bay was closed off to any visits lest anyone might see the unappealing picture and start asking embarrassing questions. Visitors were simply given some formal reasons and then denied any access beyond the buildings of the administration and housing complex. No one was allowed inside the territory, be it journalists, parliament members, or local legislature deputies, to say nothing of NGOs and their experts.

The reason why the military supervisors of Andreyeva Bay never did anything to remedy the situation for almost eight years, between 1990 and 1998, needs no sophisticated explanation. With the breakup of the Soviet Union, the country was plunged into a complete chaos, beleaguered by economic turmoil, non-payment of salaries and wages, debts it was defaulting on, bankruptcies, closedowns, and pandemic poverty. Hundreds of nuclear submarines were taken out of operation. Meanwhile, officers who served in Andreyeva Bay at the time said later that during that period, when they were waiting for salaries for several months in a row, they were forced to send sailormen out – or went themselves – to the hills to search for non-ferrous metals which they could later sell and scrape at least some money together to feed

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[10] Alexander Nikitin was arrested by the FSB (or the Federal Security Service, a successor organization to the KGB, which went defunct in 1991) on trumped-up charges of treason through espionage in early 1996, following his participation in the preparation of the Blue Report. Nikitin's arrest and the long, painstaking five-year legal battle that ensued held the attention of world media and human rights advocates as a stoical fight fought by one small man against the lawless practices of state persecution. It also earned Bellona and Nikitin himself international support and recognition. Nikitin's full acquittal in late 2000 became a major victory of Russia's nascent civil society over the secret services' powerful repression machine. This victory, however, was only to be marred in the following years by a general tightening of the screws that started with the end of Boris Yeltsin's era, a rampant – and not unsuccessful – spymania campaign, and a mounting clampdown on civil rights and freedoms in contemporary Russia, a standing concern for the international community. For more information, read on Nikitin's case at www.bellona.org.

their families. If one also takes into consideration the special mentality of the military, which dictates that "commanders always know best," and the strict discipline, and the ubiquitous Soviet secrecy and fear of contact with any "suspicious" foreigners, be they as they may have from international support programs – if one considers all this, it will become clear that the military could indeed have done little in Andreyeva Bay at the time.

Yet, since 1998 and to the present time, at least some efforts could have been undertaken to solve the Andreyeva Bay quandary. And the main question that no one has yet provided any reasonable answer to is this: Why is it that Rosatom, having received this dangerous site into its care, and understanding the full scope of its dangers, never started to develop any projects to liquidate the hazardous SNF storage facility at the base, but instead was actively engaged in appropriating the international funds and spending time on building infrastructure? That infrastructure may well have been very needed, but then why not proceed with both of the projects – removing the spent nuclear fuel in storage and building infrastructure – simultaneously? In point of fact, the very first technical design assignment to start off the task of removing SNF from the dry storage facility in Andreyeva Bay was not commissioned until early 2008. During a meeting with Norway's Prime Minister Jens Stoltenberg in the summer of 2007, Governor of Murmansk Region Yury Yevdokimov[11] said: "*One of our main achievements is that we have been able to fend off the attack mounted by the Norwegian press on a cue from Bellona leaders regarding the possible emergency situation that may arise in Andreyeva Bay…*" Could it have been that this "attack" was the very push that was needed to finally jump-start the SNF removal project? This only goes to show that the public can never part with its role of a watchdog as it makes sure that the bureaucrats don't sleep all the way to a nuclear catastrophe.

For a very long time, the impression was that many Rosatom structures, including scientific research institutes, were treating the problems of Andreyeva Bay and Gremikha as a leg-up to getting their hands on stable financing and good salaries. At some point, during a hearing on the Strategic Master Plan[12], an envoy from one of these institutes made a presentation on his institute's suggestions regarding the scope of studies that needed to be conducted in Andreyeva Bay and Gremikha. In conclusion, he detailed the cost of these works, including travel subsistence for those who would be working at these sites, as well as other expense items. Upon hearing these figures, one of the Rosatom officials present at the hearing asked: "Am I correct to understand that with this money, you are going to fly a plane and then a chopper every morning to Murmansk, Andreyeva Bay, and Gremikha, and then in the evening, after work, return back to Moscow?" Such an attitude was, unfortunately, not so uncommon.

Whatever was done in Andreyeva Bay during these several years before the end of 2007 had, in effect, no direct relation to the principal unsolved problem of the former naval base – SNF removal from dry storage blocks. In storage there are at present over 23,000 spent fuel assemblies, or 50 nuclear transportation train runs' worth of spent nuclear fuel – that, in addition to the stockpiles of over 10,000 tons of solid radioactive waste and around 600 cubic meters of liquid radioactive waste.

Rosatom takes over but the problems remain

Rosatom began its management of Andreyeva Bay in 1999 – when it still was the Ministry of Atomic Energy – by building a roof over the dry storage tanks. This means that already then it was clear that the tanks accommodating SNF from the inoperative wet storage facility contained water in them, which presented a grave problem both for the immediate and distant future. Where this water comes from still remains an answered question. In any case, there have been no official statements to that effect. But Bellona tends to believe – and this has been confirmed by the liquidators of the accident in Building 5 – that water was there in the tanks to begin with and later accumulated further as a result of atmospheric precipitation and, possibly, from underground wellsprings as well. An additional concern in this

[11] Yevdokimov left his post in the spring of 2009.

[12] The development of the Strategic Master Plan was initiated under the aegis of the so-called Global Partnership program devised by the Group of Eight industrialized nations in order to secure and clean up Russia's huge nuclear legacy amassed during the years of the Cold War and the arms race. The G-8 countries pledged to contribute to these purposes $10 billion over a period of 10 years. The European Bank of Reconstruction and Development (EBRD), which was responsible for the allocation of the funds, then set forth a requirement that a comprehensive study be first conducted to prioritize the projects in need of financing before the funds could be earmarked. The resulting Strategic Master Plan for the decommissioning and taking out of operation of the Russian Navy's nuclear submarines and other nuclear-powered vessels in Russia's Northwest was approved in December 2004 in London, during a meeting with Russia and European sponsors of the EBRD's Northern Dimension Environmental Program (NDEP). The 80-page executive summary of the Master Plan's Phase One was officially released in early 2005. The executive summary and technical volume were completed by three Russian institutions: the Russian Academy of Sciences' Nuclear Safety Institute (IBRAE), the Dollezhal Research and Development Institute of Power Engineering (NIKIET), and the Igor Kurchatov Scientific Center. This makes the plan an almost entirely Russian-conceived project. For more information, please see, for instance, http://bellona.org/english_import_area/international/russia/nuke_industry/co-operation/32077.

situation is provided by the fact that most recent samples have shown a high level of salinity in this water, and salt is known to accelerate corrosion.

The overall impression is that for a long time, Rosatom either did not understand very well or, for one reason or another, did not care to understand which approach to take to the problem of retrieving the spent nuclear fuel in Andreyeva Bay from its storage in the dry storage blocks – thus never coming to any decisions about a project or possible removal strategies. This is confirmed, for instance, by this statement made in late 2004 by Rosatom deputy head Sergei Antipov[13] at a press conference marking the completion of the roof project in Andreyeva Bay: "*As time went, water started accumulating in the reservoir, which brought forth the necessity to create such a shelter, i.e. a steel roof equipped with ventilation and a filtering system. At the moment, the reservoir with SNF is protected from outside impact. From here onward, we can already start working with the issues of extracting the fuel and sending it off for reprocessing.*" That is, until the end of 2004, no decisions had existed regarding the SNF removal project that is being developed today. For this project, the roof bears no tangible significance and will be torn down as new buildings will be constructed at the base.

In 2000, a host of projects launched a phase of dynamic infrastructure development in Andreyeva Bay, which is still in progress. Besides the roof over Tank 3A, the scope of construction has included sanitary control stations, roads, administration and living quarters, checkpoints and guardhouses, water ducts and sewage systems, canteens, and many other facilities. All of these have been put together in stages and, for the most part, with the help of international donations from Norway, Great Britain, Sweden, and other countries. When detailing the funding that is being channeled into nuclear cleanup projects in Russia's North, official sources in Russia say that the overall financing breaks down into 60 percent in Russian budget funds and 40 percent in international sponsorship money. The state, they say, is responsible, mostly, for the costs of upkeep of the onshore technical bases in Andreyeva Bay and Gremikha (a former naval base similar to Andreyeva Bay on the eastern coast of the Kola Peninsula), while international funding is spent on building the infrastructure necessary for the future management of nuclear and radioactive waste in storage at these sites. But as one looks at the projects under implementation in Andreyeva Bay, this ratio of Russia's own money versus international support, as cited in official statements, raises serious doubts. At best, it is the other way around. It is by now impossible to calculate how many millions in foreign funding has already been spent on Andreyeva Bay, but in the period of between 1998 and until the present time, Norway alone has taken part in various international contracts carried out at the base to a total cost of around NOK 140 million – or over $20 million, in mid-2009 exchange rates. This is not to count other projects that Norway helps tackle in Russia's Northwest, like decommissioning of old Russian nuclear submarines. Norway and Great Britain have picked up the almost $1.3 million tab for the construction of the roof over Tank 3A, a locker room, and two sanitary stations. The reconstruction of a 15-kilometer section of the road connecting Andreyeva Bay to the Murmansk-Pechenga highway lightened Norway's pockets by another NOK 15 million (or $3 million) – at NOK 1 million ($200,000) per one kilometer of a one-lane road.

2003 saw the completion of "Norwegian Village," an administration and housing complex intended for the Andreyeva Bay personnel. A sewage system equipped with waste treatment facilities was built as part of the same project. All sanitary wastewater now has to undergo biological treatment before it is dumped into Motovsky Bay. Negotiations are also under way today with Norwegian partners to add a second story to the complex since, in SevRAO's assessments, additional premises may be needed for the engineering and technical staff when SNF removal works commence. A guardhouse and part of the physical security perimeter have also been built at the expense of Norwegian taxpayers. The country's government donated NOK 20 million to this project.

In 2003 and 2004, a Coordination Group was formed to tackle Andreyeva Bay problems, which comprised representatives from Rosatom, a number of Russian-based organizations, and two donor countries participating in the environmental rehabilitation efforts in Andreyeva Bay – Norway and Great Britain. The Coordination Group raised the issue of working out a comprehensive rehabilitation program for Andreyeva Bay, and the Norwegian position was that it was a priority that a Master Plan be developed for the works at Andreyeva Bay, complete with environmental impact studies for each individual project. In November 2004, an SNF management strategy was finally adopted for Andreyeva Bay. After that, in 2005, the All-Russian Scientific Research and Design Institute of Complex Energy Technologies (VNIPIET)[14] began working on an investment feasibility study for the international project of environmental rehabilitation of the onshore technical maintenance base in Andreyeva Bay. As was then detailed in a statement by SevRAO deputy director for international projects Vladimir Khandobin, "*[...] What we are talking about is investments needed to start the removal of [spent] nuclear fuel from the territory of the base and the selection of sites for the construction of new storage*

[13] Antipov left his post as Rosatom's deputy chief in 2006.

[14] In September, 2008, this St. Petersburg-based institution was transformed into a joint stock company East European Head Scientific Research and Design Institute of Energy Technologies.

facilities […] After which individual contracts will be signed regarding the compaction of solid and liquid radioactive wastes and the construction of an SNF management complex."

At the same time, Rosatom's International Center for Environmental Safety, the Dollezhal Research and Development Institute of Power Engineering, and SevRAO signed a number of deals with the British firm RWE NUKEM Ltd[15]. The contracts envisioned the construction of the building to house the future SNF storage facility, developing a technology for the management of the SNF in storage, providing safe conditions for the storage and management of SNF in the dry storage blocks, as well as working out a series of measures to ensure radiation safety when performing operations at the work sites. The overall costs of these projects were estimated at GBP 2.425 million.

Besides bringing new infrastructure to Andreyeva Bay, other projects included renovation of the old facilities and buildings that there were still plans to continue using in the future, and the demolition of those that were no longer needed. In particular, renovation works started on Building 50 to reequip it further as a lab and a specialized laundry facility to handle contaminated clothing. Two yards were being built for decontamination of transport vehicles. Great Britain had earmarked GBP 3 million to tear down old unneeded buildings. Two prefabricated sanitary control stations were ordered in Severodvinsk, each of which with a capacity to service 80 people.

The old technological pier presented a special problem, as its condition was far below satisfactory. Dilapidated as it was, it was also sliding off the shore, bearing heavily on the "new" pier, which, too, needed renovation and modernization. Building 1, which was near the dry storage tanks and which housed the electric power substation, was torn down. Power supply was now provided by a new substation of the modular type. These works had been financed by Great Britain.

In late 2006, the old pier was finally dismantled and work started to renovate the new technological pier. The new pier was intended for support vessels with a displacement of up to 14,000 tons and a maximum draft of 8 meters, but its construction had been halted back in 1998 and never finished. The new pier was not the only facility that needed additional work – construction was never completed on the utility bridge, which was then supposed to be connected with the pier. The issue of the new pier came up again in 2002, when the Russian side was carrying out a comprehensive radiological survey of the territory of Andreyeva Bay. In the course of this survey, which was being done with the financial help of the Norwegian Radiation Protection Authority[16], the old pier was flagged as one of primary radiation hazards at the base: In some places on the pier, contamination levels reached between 460 and 1,000 microsieverts per hour. In 2005, again with the support of the Norwegian side, Russian engineers performed a structural examination of the new pier, including both its above-water and underwater parts. The examination showed that in the condition that it was in at the time, the new pier could not be used, but further renovation might render it serviceable in the future. The same examination revealed that the old pier not only presented a radiation risk, but a technological one as well, as it was sliding underwater and pushing against the new pier. The decision was made to tear the old pier down.

Renovation works on the new pier were financed jointly by Norway and Great Britain. In 2007 alone, Norway earmarked NOK 20 million to the purpose. The UK agreed to give the funding needed to install a rail-mounted gantry crane on the new pier.

In 2006, the boiler house – Building 12 – was demolished, and what was left of the fuel oil and diesel fuel at the facility, and the remaining wastewater, polluted with fuel oil, was recovered or disposed of. At the same time, works started on building a landfill for construction waste. All of these projects were financed by Great Britain.

Late that year, a management group was formed to coordinate all projects under development in Andreyeva Bay and specifically, for the management of projects for which funding was being provided by Great Britain.

Early in the following year, a long-term work schedule was put together to serve as a basis for budget planning, mapping out future expenses, and pooling the resources necessary for cleanup and remediation projects to be launched in Andreyeva Bay. It was at the same time that negotiations started with the European Bank of Reconstruction and Development (EBRD), the prospective sponsor of Andreyeva Bay efforts, on the problem of taking out of operation and further decommissioning of Building 5. Work

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[15] Renamed Nuvia Limited in May 2008, the British company RWE NUKEM Ltd – until 2006, part of a global trader of uranium, conversion, and enrichment services, the German-based RWE NUKEM Group, and now wholly owned by the French Soletanche Freyssinet - is active in the market of specialized civil engineering and provides a wide range of services to the nuclear industry, including design and build, waste management, decommissioning, radiation protection, and nuclear R&D. It still is involved in projects in Andreyeva Bay, working there on behalf of the UK Government.

[16] The Norwegian Radiation Protection Authority (NRPA) is a structure of the country's Ministry of Health and Care Services that oversees the area of radiation protection and nuclear safety in Norway. As such, it is responsible for supervision of the use of radioactive substances and fissile materials, coordinating contingency plans against nuclear accidents and radioactive fallout, and monitoring natural and artificial radiation in the environment and at the workplace, among other functions.

continued on engineering an additional protective shield to be installed over Tank 3A. A decision that building this additional layer of protection was needed was made following a monitoring survey of all three dry storage tanks, Tanks 2A, 2B, and 3A. The survey made it clear that the dangerous levels of radiation showing above the tanks' surfaces would not allow for safe implementation of SNF retrieval works, while a new layer of protection would help bring these high levels of radiation down. Besides, the construction of the main building that was planned to be erected over Tanks 2A, 2B, and 3A (Building 153) was obstructed by the tanks with liquid radioactive waste that were also there (Tanks 2C and 2D). This prompted the extraction of liquid radioactive waste from these tanks and preparations to remove the tanks from the site. These works are being implemented with funding provided by Great Britain. In 2007 alone, the UK sponsored GBP 6 million's worth of cleanup and environmental rehabilitation projects in Andreyeva Bay.

On July 31, 2007, the two modular sanitary stations, ordered earlier in Severodvinsk, were taken into operation, as well as the decontamination yard for transportation vehicles and a radiochemical laboratory bought with British funding and housed on the renovated premises of Building 50. This same building now accommodated an automated radiation control system. A physical security system for the sites of the Andreyeva Bay territory was also put into operation. Additionally, the Russians suggested building new access roads at the base and repairing old ones. A decision was made as well to examine the condition of the 40-ton KPM-40 lifting crane, which stood near the dry storage tanks, to establish whether it was fit to be transported to the pier and if it could be used further during the construction of the new SNF management complex. In the same period, designing works were completed on the canteen, the garage, and a roofed yard for the storage of empty containers for solid radioactive waste. The actual construction of the canteen, a NOK 18 million project that also includes building a training facility in Andreyeva Bay, was slated to begin in 2009. This same year, works are scheduled to start on another project, which envisions connecting Andreyeva Bay to the power supply grid in the nearby town of Zaosersk. The removal and further transportation of spent nuclear fuel from Andreyeva Bay requires no less than 10 megawatt of electric power, which warrants an examination of the power network that will have to be used as the project goes under way.

In late October 2007, a grant agreement was signed with the EBRD that sealed the first phase of decommissioning of the defunct wet storage facility at Building 5. By end 2008, demolition works were completed on Building 11, Building 1, including the basement, Building 8, and Building 35.

Meanwhile, in July 2008, an agreement had been signed between Russia and Italy that launched the project of designing and building a specialized vessel for the transportation of spent nuclear fuel and radioactive waste. The EUR 71.5 million project, fully financed by Italy, includes the costs of design and construction, both commissioned to the Italian firm Fincantieri. The future containership with a deadweight of 4,000 tons is scheduled to be floated in 2011. The vessel's specifications are as follows: 84 meters in length overall, 14 meters in beam, 16.7 meters in height, and a maximum draft of 4 meters. The ship will have two isolated cargo holds with a combined capacity of 720 tons and capable of accommodating up to 18 containers with SNF weighing 40 tons each. For transshipment operations, a 45-ton electrohydraulic rotating crane will be installed onboard with a boom reach of between 4 and 15 meters. The vessel will be able to travel at speeds of up to 12 knots and make non-stop voyages as long as 60 days. Its design operational range is 3,000 nautical miles. As the future owner and operator of the vessel, Rosatom chose Atomflot – the Murmansk-based nuclear icebreaker operator that had just prior to the contract signing been severed from its parent company, the Murmansk Shipping Company, and put under Rosatom's control. Because it will be ice-reinforced, the containership will be capable of serving in the Arctic seas during the summer and fall navigation periods.

In late 2007, Rosatom announced a tender looking to select a general contractor to work on the designing, building, and taking into operation of infrastructure sites and facilities pertaining to the management of spent nuclear fuel and radioactive waste at what authorities have officially been calling the Temporary Storage Complex in Andreyeva Bay.

The following important terms and conditions, as well as cost estimates, were detailed in the tender announcement:

- Final deadline for taking into operation the infrastructure sites and facilities pertaining to the management of spent nuclear fuel and radioactive waste at the Temporary Storage Complex in Andreyeva Bay: Year 2012.
- The project will be implemented with funding received from non-budgetary sources. The construction of Building 154/155 will be carried out as part of an August 31, 2006 international agreement No. DTIFSU/P89500/ADM/001 signed under the aegis of the Framework Agreement on the Multilateral Nuclear Environmental Program in the Russian Federation (MNEPR)[17] and its first

[17] MNEPR was signed by Finland, Sweden, Norway, Denmark, the United Kingdom, Germany, France, Belgium, the Netherlands, Russia, and the European Commission, in May 2003. With the signing of the protocol, many tax and liability issues were eased, making future bi- and multi-lateral

stage of implementation. The construction will be financed by the British Government's Department of Trade and Industry[18] out of the $750 million pledged by the UK Into the Global Partnership program[19].

- A preliminary cost estimate for all the sites of Andreyeva Bay is RUR 8.8 billion[20]. (The preliminary cost estimate is an approximated figure and will be further adjusted with the elaboration of project documentation).

The announcement also underscored this important condition: Tender participants were expected to be holders of Rosatom-issued licenses to perform design and construction of buildings and infrastructure complexes and licenses authorizing them to work with information constituting state secrets, as well as licenses issued by another organization, Rosstroi[21], to act as general contractors under designing and construction projects.

For one thing, this meant that the tender was exclusive to Russian-based organizations and foreign entities were not entitled to participate. Secondly, this implied that Rosatom had essentially announced the tender for none other but itself, since no outsider organization that had no connection to Rosatom could have any realistic hopes to win the tender. It is noteworthy, however, that despite the secrecy and the safeguards provided to ensure non-disclosure of classified information, representatives of foreign states and foreign companies were still admitted to taking part in the project. Moreover, some of those – like RWE NUKEM Ltd – are leading project participants.

The role of the chief developer in the project to build the spent nuclear fuel and liquid radioactive waste management facilities at the Temporary Storage Complex in Andreyeva Bay was given to VNIPIET, which in early 2008 was commissioned with a technical design assignment to come up with a development project for the construction of the SNF management complex. The Dollezhal Research and Development Institute of Power Engineering was appointed the project's scientific supervisor.

The exact timeframes for the pending design and construction works were still under debate. "*The first container with spent nuclear fuel will be transported out [of Andreyeva Bay] in 2010*," Governor of Murmansk Region Yevdokimov had said during the summer 2007 meeting with Norway's Prime Minister Stoltenberg. Later, Rosatom pushed the SNF removal deadline back to sometime around 2011 or 2012. Regarding the project of actual extraction of the spent nuclear fuel from Andreyeva Bay's dry storage tanks, an unequivocal statement from Rosatom announced that documentation on that project was to be completed by the end of March 2009 at the latest. Rosatom also promised to arrange public hearings on the project of SNF retrieval from the dry storage blocks.

But as of November 2009 – the time when the present report was being prepared – no information had surfaced on the completion of this project's design documentation, nor with regard to a specific date for the expected public hearings.

SNF extraction project

A transportation scheme was now devised by which spent nuclear fuel in storage in Andreyeva Bay was supposed to be first taken to the yards of the nuclear icebreaker operator Atomflot and then shipped off by rail to the Ural-based chemical combine Mayak for reprocessing.

Before that, however, the primary issue that needed to be dealt with was how exactly spent nuclear fuel was to be retrieved from its dry storage cells. Only after a solution had been found to this problem could project developers finally go ahead with putting the project together.

To solve the SNF extraction dilemma, experts from Russia and Great Britain conducted scientific studies which revealed – in Rosatom's assertions – that there were no options to guarantee safe removal of spent fuel assemblies from the dry storage tanks. The studies showed that while extracting spent fuel assemblies out of their dry storage cells, it was impossible to rule out potential damage that the casks with the assemblies might sustain having to do with the risk that the bottom parts of the casks might

agreements for nuclear cleanup and security easier. It also opened the floodgates of NDEP Nuclear Window, a fund held by the EBRD for nuclear cleanup in Northwest Russia. For more information, see http://www.bellona.org/subjects/MNEPR.

18 In a 2007 governmental reform, this department was disbanded with the creation of the Department for Business, Enterprise, and Regulatory Reform (BERR) and the Department for Innovation, Universities, and Skills (DIUS). In June 2009, these two were merged, forming the Department for Business, Innovation, and Skills.

19 See Footnote 5.

20 The preliminary cost estimate was stated in late 2007. In mid-2009 exchange rates, this approximates $282.5 million.

21 Rosstroi, a Russian acronym standing for Russian Construction (earlier, State Construction, or Gosstroi), is the government's Federal Agency for Construction and Housing and Utilities Sector.

break off during the operation. Likewise, scientific institutions specializing in metal physics could not vouch 100 percent that the casks with spent fuel assemblies would remain intact while being extracted from the cells. The immediate task, therefore, was to choose an implement that would help keep a cask's bottom attached during the retrieval, pull the cask safely out of its storage space, and move it into a hot cell for shielded containment. The task, however, proved to be a wild-goose chase.

If the bottom of a cask with spent nuclear assemblies were to break off during the extraction, the assemblies would simply fall out of the cask back into the storage cell. With water present in the storage cell, specific conditions might be created for the occurrence of a spontaneous chain reaction. Project developers also had to allow considerations for the fact that there were no precise data on the total energy yield of particular spent fuel assemblies. This meant that, in accordance with regulatory norms, an evaluation of the risk of a spontaneous chain reaction in the conditions at hand was supposed to be performed in the same way such evaluations are made for fresh fuel assemblies – i.e., based on more rigorous initial values. Meeting this requirement proved next to impossible, so an alternative was settled upon – to change the entire approach to the process of extracting SNF from the dry storage cells and its further management.

It was initially planned that the SNF would be removed from the dry storage tanks cask by cask, meaning that spent fuel assemblies would be extracted from the cells while still contained in a cask. The cask would then be placed in a hot cell, where the assemblies would be "recasked" – placed into a transportation cask – one by one for future shipping to Mayak.

Altering the approach to the SNF handling problem resulted in a decision that the spent fuel would not be extracted from the tanks cask by cask – but rather, assembly by assembly. The cask-by-cask option was meanwhile shelved as a backup solution, in case taking the spent fuel assemblies out one by one failed the expectations.

This approach was finally adopted for the handling of SNF in Andreyeva Bay's dry storage tanks and as the basis for VNIPIET's assignment to develop the technical design of the SNF management complex.

Experts' comments

Anatoly Safonov, liquidator of the accident in Andreyeva Bay.

I have seen casks breaking apart, but I have never seen or heard that cask bottoms would fall off. We have observed casks getting torn in mid-section because of the water that accumulated in them and then froze. But even in such conditions, it was not the bottoms that would get destroyed, but the walls of the casks. I have never seen a cask bottom that would be torn away from the cask by ice. There was one case when bottom ends would fall off Type 6 containers. But the cause of that was that the screws that kept the bottoms attached to the main frames would loosen and give way.

I know what it means to recask fuel assemblies one assembly at a time. We did that ourselves, manually, several times in Building 5. This is a lengthy and dangerous process. When you take off the top lead plug, you find highly radioactive filth inside that "shines" at levels of up to 100 roentgen per hour. If a machine does this work, then all of this filth will get spread around inside. If people will do the work, they will be exposed to substantial doses of radiation. Let me affirm here that most of the fuel assemblies that were unloaded from Building 5 are either damaged or completely destroyed. Of course, the degree of damage may vary. While unloading casks with SNF from Building 5, we had to pierce the red-copper membranes to drain water out of the casks. The method of perforating the membranes was the following: The cask would be dropped off a height of around one meter down on top of a sharp shiv that was made of steel and welded to a thick sheet of metal. Then, to drain the cask completely of water, we used an out-of-balance electric motor that we placed on the top end of the cask. We would run the motor for several minutes and it would shake the cask together with the SNF in it, pushing the remaining water out of it. During these operations, the fuel assemblies would, of course, undergo a significant dynamic shock. The radiation emitted by the water that we used to drain out of the casks would sometimes reach up to 60 roentgen per hour, which was evidence that the fuel rods had come in contact with the water. The reason I am saying all of this is that if the SNF is extracted assembly by assembly, then the levels of radioactive contamination will be colossal. All of the equipment will get contaminated very quickly and using it will become impossible.

Sergei Yermakov, former chief engineer at BTB 569 in Andreyeva Bay, currently research fellow with the Alexei Krylov Shipbuilding Research Institute

I don't personally know any cases when the bottom of a cask would break off. I seriously doubt it that a welded cask bottom would simply fall off just like that. Taking each spent fuel assembly out one by one is painstaking and dangerous work. From the point of view of radiation safety, it's much more dangerous than taking the fuel out together with the cask. From the point of view of nuclear safety, there are measures that can be thought of to ensure against the development of a spontaneous chain reaction in case spent fuel assemblies fall out of the cask, for instance, creating a system that would involve an efficient use of liquid or other kinds of absorbers. This is an issue for scientists and designers, but extracting the fuel assembly by assembly will result in that the removal will take at least a dozen years, with huge radiation exposure problems for the people and the environment.

Yury Chernogorov – *former chief process engineer at Atomflot, currently an expert with Bellona*
The technology of assembly-by-assembly retrieval has never been used anywhere, it has not been tested by practical application, and is very questionable in terms of reliability. We are dealing with SNF here, so we cannot afford any doubts. Therefore, as experience dictates in such cases, before adopting such a strategy, both the technology and the equipment to be used need to be challenged by experimental testing. It is also necessary to compile and agree on a list of potential contingency situations – and the ways of liquidating their consequences – exactly in those places in the dry storage facility where there is water in the pipes and where the situation with radiation safety is especially harsh. In my opinion, options for the following eventualities must be provided for in this list:

- checking whether it is possible to remove water from the pipe where the cask under testing is located, along with keeping control over the level of the remaining water;
- finding a cask with a retaining screw that resists loosening so that the top protective plug of the cask becomes impossible to take off; making sure to loosen such a screw or remove it using a technology specially devised for such cases – for instance, by cutting through it with the help of a drill; removing the top plug (there will be a very large number of casks with problems like that);
- checking whether it is possible to home the reloading equipment on the first SFA in the cask once the cask's top plug is removed; verifying guidance precision by using a special gauge to grip the top mushroom-shaped end of the SFA with it;
- checking for how easily extractable the SFA is by lifting it manually to a height of 200 to 300 millimeters, holding it with the gauge that was used to verify the precision of the homing; placing the SFA back into the cask after that;

If the SFA does not yield to manual lifting and requires that a bigger effort be applied, such an assembly will have to be extracted using special equipment and a dynamometer that would prevent exceeding the stress applied beyond the value permitted for such cases by reactor core design specifications. If the SFA resists lifting even at an increased effort, a technology must be developed to deal with the consequences of such a situation without resorting to further increases in the lifting force. One must not allow damage to the fuel-containing sections of the SFAs: The fuel rods may break loose from the bundles and fall back into the pipe. Retrieving them from the pipe will present a serious problem and the personnel will be exposed to severe doses of radiation.

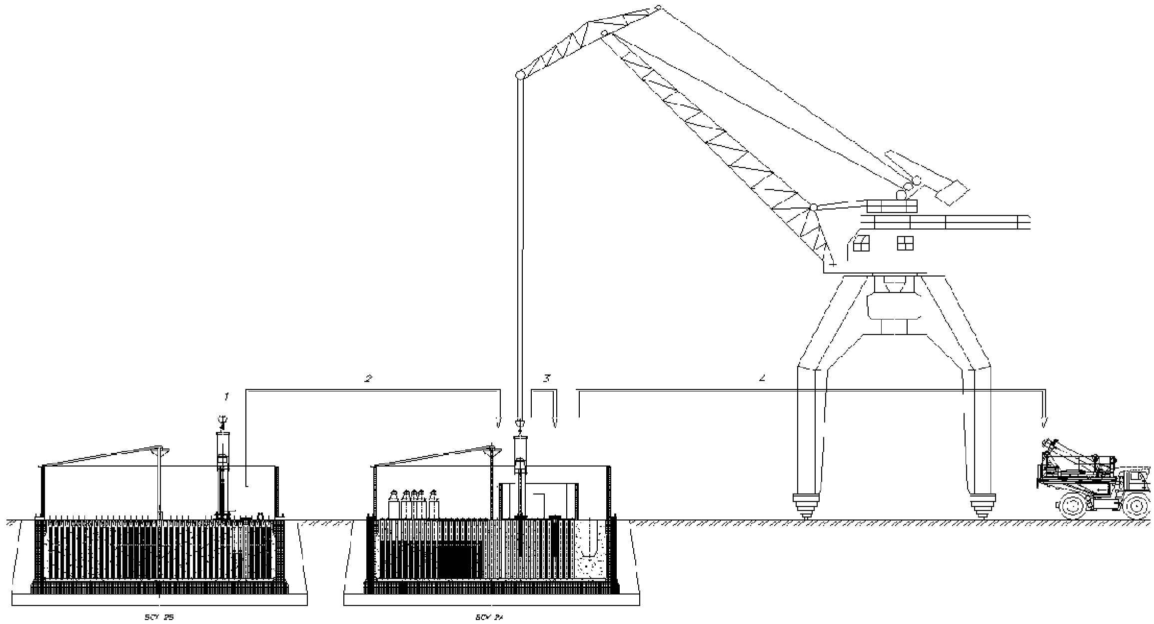
Alexei Kalashnikov – *a researcher, former chief nuclear safety inspector*
I have very strong doubts that this operation will be safe from the point of view of radiation danger. And that being so, there will be big problems personnel-wise, since they will have to be unloading this fuel year on, year out for ten or 12 years. The human factor will play a fundamental role in this operation. Today, no one will agree to be exposed to high radiation doses just like that.

Yet, after all existing options were examined, Rosatom adopted the strategy that conformed to the described approach.

The Russian nuclear authority was looking at two strategies to handle the task of removing SNF from the dry storage tanks. The first strategy itself forked into two distinct extraction options.

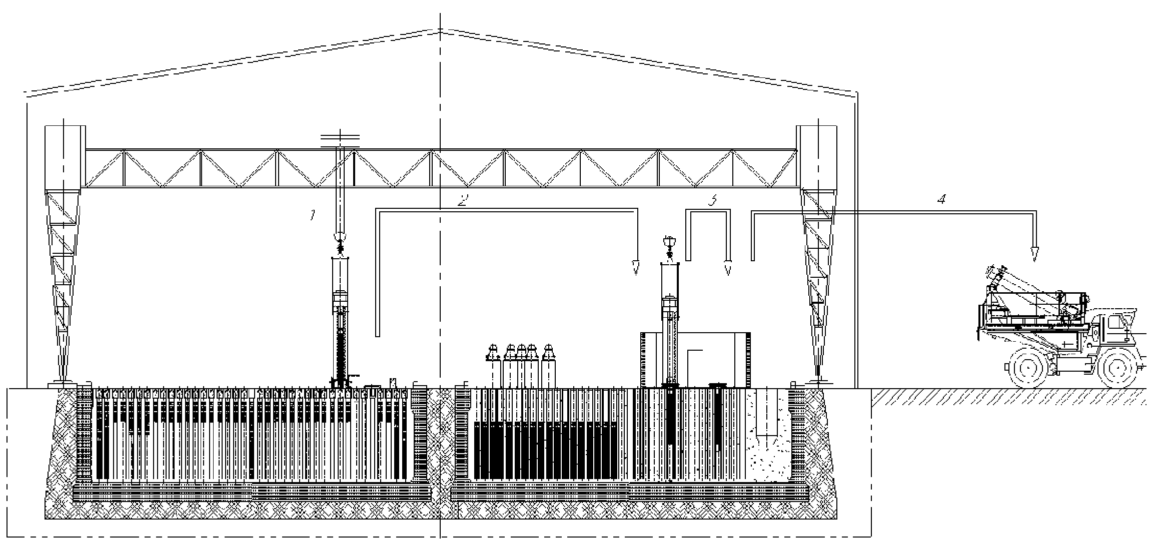
SNF extraction: strategy one

Option One of Minatom's Extraction Strategy One implied taking the spent nuclear fuel out of storage in the dry storage tanks using the existing equipment – namely, the KPM-40 lifting crane still on site in Andreyeva Bay. In essence, this method simply mirrored the technology that had been used 15 years ago, when the fuel was being loaded into the storage cells.



Option One of Minatom's Extraction Strategy One.

Option Two of this strategy expanded slightly to allow for certain construction works to be carried out before removing the SNF. The idea was to build a carcass-like structure over the tanks and install the lifting device inside this structure, further equipping the site with a loading and recasking station where all removal operations would be taking place.



Option Two of Extraction Strategy One.

SNF extraction: strategy two

This strategy envisioned unloading the fuel assembly by assembly and recasking the assemblies outside the existing dry storage facility. Several stages of this process were under consideration in a variety of options, but the main principle was to remove the SNF one fuel assembly at a time, while the recasking was to be done at a different site other than the dry storage tanks.

Rosatom carried out a comparative analysis of the two strategies to evaluate each from the point of view of safety and reliability, as well as to see which promised to be most time-saving and cost-effective.

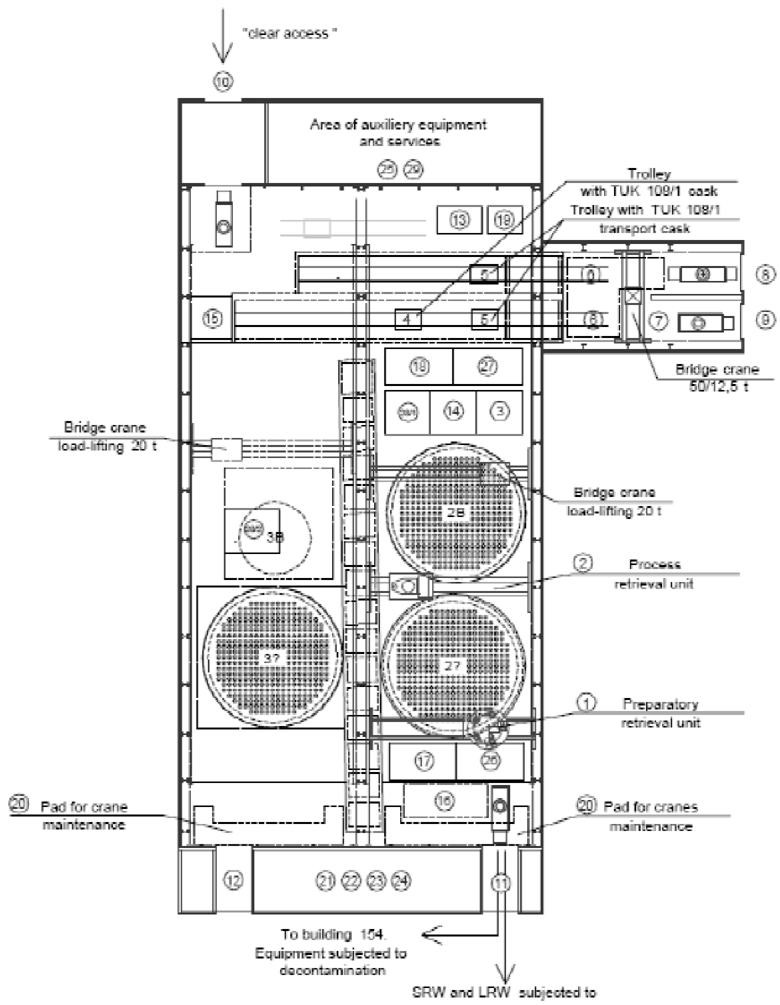
In Rosatom's conclusions, Strategy Two was the safest, most reliable and expedient, but also the more expensive one. The entire SNF management complex was to carry a price tag of nearly $500 million. Yet, despite the high costs, the decision was made to settle on this second extraction strategy.

Finally, in early 2008, VNIPIET received its technical design assignment to work on the development project for the construction of the SNF management complex in Andreyeva Bay.

The complex to be designed and built at the former naval base includes the following facilities:

- A new pier;
- Future Building 153 to house a recasking station and a loading area to transfer SNF casks into containers;
- A buffer storage facility – Building 151 – to accommodate SNF-holding containers ready to be shipped off to Mayak;
- An auxiliary maintenance and services area – Building 154 for the decontamination and repairs of equipment to be used while handling spent nuclear fuel.

The first and foremost step to be implemented under the project would be putting together Building 153.



Before Building 153 is in place, Rosatom plans to perform a series of preparatory works, such as taking down the old concrete tanks with liquid radioactive waste from the site in immediate proximity to the dry storage tanks, removing the containers stored near Tank 3A, dismantling the KPM-40 crane, demolishing Building 34, and drilling several wells to provide water supply to the future recasking and container-loading facility. In addition, a horizontal shield will have to be placed on top of the tanks as biological protection from the emitted radiation. For that, the concrete slabs that were installed in Tank 3A – many of which are heavily contaminated – need to be removed, the surface of the tank will have to be decontaminated, and all of the concrete plugs that could only partly be inserted into the top sections of the storage cells to secure the SNF loaded in the pipes – and which therefore protrude over the tank surface – will have to be taken out. The pipes thus left without the protective plugs will then have to be covered with less heavy lids, and only then will the horizontal protective shield be placed over the tank, which would allow to start construction works at the site. In designers' projections, this protective shield will be needed in the future, when the main extraction operations begin, so that the reloading machine could start preparing the cells for SNF retrieval.

The horizontal protective shield will thus be expected to carry out a dual protective duty: Providing safety while constructing Building 153, which is needed for the handling of the extracted SNF, and during the actual extraction, as the transfer machine retrieves SNF assemblies out of storage cells. The plan was that the first installment of the protective shield – the segments to be laid over Tanks 2A and 2B – would be in place already by the end of March 2009, as according to Rosatom's assessments, background radiation levels over these tanks are less severe than those near Tank 3A. Rosatom's data indicate that Tank 3A was the first one to receive the spent fuel transferred from the faulty Building 5, so the radiation risks it poses are the worst of the three tanks. Upon being loaded, this tank was covered with concrete slabs and what exactly is buried under them is still open to speculation. Surveys carried out by the Dollezhal Institute do not provide a complete picture of what conditions exist in Tank 3A or what challenges installing the protective shield over the tank would entail.

Experts Bellona was in contact with say that It is quite possible that radiation levels around Tank 3A are so high mostly because it was the storage cells closest to the tank's rim that received a lot of the "crumbled" fuel. This was done for the reason that it was practically impossible to load SNF casks into those outermost cells of Tank 3A, which is why those cells were used for various waste, including spilled fuel composition. The rest of the cells in Tank 3A were loaded with fuel delivered by technical maintenance vessels, that is, with fuel that was in a much better condition than that removed from Building 5. Tank 3A was loaded with no more than 50 or 70 damaged casks with defective SNF from the right-wing pool of Building 5. Most of the fuel from the faulty storage facility went into Tank 2A. Tank 2B was used for a long time as a sort of a maneuvering space, for storing fuel delivered by maintenance vessels arriving in Andreyeva Bay, which later was unloaded to be shipped to Mayak. So Tank 2B should be unloaded first, because it is dry and contains no damaged fuel from Building 5. Then move on to Tank 2A, because though it is loaded with SNF from Building 5, it is not flooded with water so badly. Tank 3A should be taken the last.

The technical development project detailing the installation of the protective shield over Tank 3A – a task carried out by the Severodvinsk-based scientific research and technological design enterprise Onega[22] – was completed in August 2008. The shield is expected to be in place covering all of the three tanks in the first three months of 2010. Once it is installed, it will be time to start putting together Building 153. Before that, however, the main operations site will have to be prepared, which involves a series of preliminary works listed above. The situation at the site is such, though, that it rules out implementing these tasks at least two or three at a time, and each may delay the completion of the next one. For instance, in order to lay the horizontal protective shield over Tank 3A, the KPM-40 crane will be needed – therefore, the crane must not be dismantled before the shield is installed. The dismantling itself will take another three months. Then, to prepare the site for SNF retrieval, the old concrete tanks that hold liquid radioactive waste have to be removed from the site, and doing that is impossible because they are located right under the crane tracks. All of this means that the time frame for the main SNF extraction operation is heavily dependent on the completion of many other tasks and thus keeps getting pushed back as smaller projects are tended to one by one.

SNF extraction technology as suggested by Rosatom

The retrieval of SNF assemblies from their dry storage cells in Andreyeva Bay is planned in the following order: Tank 2A, Tank 2B, and finally, Tank 3A.

First, water will be pumped out of the dry storage tanks, bringing the water level down to top sections of the SNF casks in the cells. The main adopted strategy for SNF removal is extracting the spent fuel assemblies one by one, without the casks they are stored in. The following operations are envisioned while implementing this strategy:

- Dismantling a segment of the horizontal protective shield and removing the top cover of the cell being unloaded to provide access to the top section of the SNF cask inside. The old concrete plugs and other objects that may obstruct the retrieval process will be removed earlier on during the installation of the protective shield.
- Placing an auxiliary module (or preparatory retrieval unit) over the cell to prepare the cell and the cask in it for fuel extraction.

[22] Onega, Russia's base center for nuclear submarine repair technologies, is part of one of Severodvinsk-based shiprepairing yards, Zvyozdochka, which since its foundation in 1946 has been building, repairing, and more recently, dismantling Russian nuclear submarines.

- Removing all waste or water that may be found in the cell.
- Removing the top lead plug of the SNF cask. If necessary, cutting out the bayonet locks in the top section so as to ensure that the plug will rotate freely enough to be removed and give access to the fuel inside. The lead plug and the waste generated during cutting will classify as solid radioactive waste.
- Inserting a stopgap plug to replace the lead one, then reinstalling the removed segment of the protective shield.
- Removing the auxiliary module and installing the main reloading unit to the specified task position.
- Dismantling the segment of the horizontal protective shield and the temporary plug.
- Extracting spent nuclear fuel assemblies – if found intact – one by one from their SNF cask.

Several tests will have to be carried out to evaluate the chances of successful extraction of spent fuel assemblies. The tests will ensure that:

- The assembly is extractable and is not stuck in the cask;
- Its weight is within permissible limits;
- It is visually observable and does not look damaged;
- The fuel is intact – verified with the help of gamma scanning.

If a spent fuel assembly gets stuck and resists extraction, it will be left unmoved. If an assembly fails to meet the requirements of any other tests, it will be reloaded into a larger cask specially designed to hold damaged nuclear fuel. After an assembly is extracted from a storage cell, a neutron absorber can be placed into the cell with the others to rule out the risk of occurrence of local criticality in the future.

Spent fuel assemblies are extracted into a hermetically sealed collector of the reloading unit. The collector can hold up to seven SFAs. Once the collector is full, the reloading unit will be placed over a reloading, or transfer, container holding separate casks to receive SFAs according to their status – damaged or intact – for temporary storage and shipping. There, the SFAs are loaded into their new cask, which the collector moves from the transfer container to a nearby transport container of the type TUK-18 or TUK-108. These transport containers[23] are used for both short-term storage and transportation of spent nuclear fuel.

After either a TUK-18 or TUK-108 container is fully loaded, it is placed for temporary storage in Building 151, where it will be held before being loaded onto a containership for a voyage to the port of Murmansk and further transportation by rail to the chemical combine Mayak. The container will be checked for radioactive contamination before it is taken out of Building 153.

Those casks in the dry storage tanks that turn out to be holding damaged fuel or SFA fragments will be extracted from their cells into the reloading unit. The machine will then transfer such a cask into a case installed in the reloading container. Cases with old SNF casks will also be loaded then into a TUK-18 or TUK-108 container supplied with a modified removable section.

According to Rosatom plans, this extraction strategy does not provide for the retrieval of "crumbled" fuel composition – particles of spent nuclear fuel that may be found in certain dry storage cells – and this fuel will remain in storage in the tanks until such time that the dry storage facility is fully taken out of operation. Surveys taken of the technical condition of the tanks have confirmed that the tanks' concrete structures are sound and reliable, with carbonation remaining at a low level.

The main problem that project designers believe will persist as the retrieval operation goes under way is the actual challenge of extracting spent fuel assemblies from their casks in dry storage cells.

The technology under development for this operation implies the use of two machinery units – a preparatory retrieval unit, or auxiliary module, which will prepare the cells and casks in them for SFA extraction, and the process retrieval unit, or the main unit of the reloading machine, which will be used namely for the SFA-by-SFA extraction of the fuel and the delivery of the assemblies to the recasking facility.

This is how a representative of the project's main developer, VNIPIET, commented on this process: "*…The way we see this is that the problem of extracting spent fuel assemblies from significant depths (around two meters) may be solved by this method: Guideways and a chute, which comes very close to the top section of the cask, are installed on the top cover with the help of the reloading machine. A television camera is fixed in place on a console and is homed in on an adjacent SFA. The homing mechanism is the following: A cross sign is put on the screen of the video control device and the camera*

[23] TUK is the Russian abbreviation for "transport packaging container."

is guided over the grip so as the cross arrives exactly at the centre of the cask's upper end. This technology will allow for what will practically be a surgical zeroing-in on the desired mark. Because the grid in the casks is a regular one, we can, by turning the homing device installed on top at specified steps, target with pretty good precision the next SFA in the cask. Which is to say that the main task is to "capture" the fist SFA, the rest is purely mechanical. […] This on-the-mark guiding will be provided for by the design of the machine and ensured with three types of control. The first is how easy the extracting goes. Here, it is all checked against the stress of the dynamometer; if the SFA is not defective, then it has to let go at a force of 20 kilograms. The machine itself already provides for this element of control. SFA integrity control is done through video observation. And the next element of control is checking for the integrity of the nuclear materials with the help of gamma scanning. Gamma scanning will be provided each time an SFA is being extracted. These are the three types of control that will be in place while retrieving SFAs from a cask. Extraction data will be automatically logged in a special record-keeping system… […] This is the technology we are envisioning for now…"

Rosatom has admitted that one of the hardest decisions ever has been made with regard to the SNF removal dilemma in Andreyeva Bay, but the situation is a desperate one…

Independent observers have been skeptical about the technology suggested for the SFA-by-SFA extraction strategy. The reasons for their doubts are the following:

- In these experts' opinion, it will prove an extreme challenge to home the grip on the top section of an SFA with the help of machinery only, without manual handling, or to check whether the container will accommodate the SFA, without using a special gauge. Such gauge is not provided for by the design of the reloading machine.
- In each storage cell, the cask will have been loaded at an angle, not strictly vertically, or its position inside the pipe will differ cell to cell, as the cask abuts the cell's wall, for instance, or stands at a certain distance from the wall. In other words, the casks will not be found standing in a predictable pattern. All of this will cause problems with the targeting and gripping. There will be nothing "purely mechanical" about the extraction. This is why, if it is not the entire cask that is being pulled out and if it does not stand exactly upright in the cell, the likelihood must be assumed that extracting SFAs out of a cask standing at an angle will be practically impossible, since a successful extraction implies that the slant angle makes for no more than one degree.
- It is unclear what course of action could be pursued if an SFA under extraction gets stuck midway through the storage pipe – that is, when the SFA is halfway out of its cell, but it fails to budge any further and is impossible to load back into the cell. The only remaining option will be to cut the assembly in two. However, if the cutting is done across the fuel-containing section of the SFA, then the whole retrieval complex will be heavily contaminated and, possibly, rendered unusable for further operation.
- It is likewise unclear what methods exist for extracting damaged SFAs, of which there are many in the storage tanks. Will the reloading machine be used on these as well or has any other technology been thought of for such situations? A related question arises with regard to how exactly the lead plug of an SNF cask will be cut out if it is found stuck to the frame of the cask due to corrosion and resists removal, or if the same proves to be the case with the lid of a storage cell.
- How long will it take altogether to retrieve the almost 23,000 spent fuel assemblies if the removal proceeds in accordance with Rosatom's scenario, and how many people will it involve, considering the high doses of radiation exposure assumed during the task and the resulting high personnel turnover?

In response to these and other concerns, Rosatom assures that the technological equipment it plans to use for the retrieval operation will be sufficient to solve successfully all of the technical problems mentioned above. The Russian nuclear authority cites the extensive experience gained in similar endeavors in Great Britain, France, and Sweden. This experience has also been put to test at a range of sites formerly under the purview of the Russian Ministry of Defense, Rosatom says. Furthermore, special simulation benches have been put together at various scientific research and design organizations where work has started assembling pipe models standing at different angles of inclination to imitate a section of the dry storage facility in Andreyeva Bay. Mockup copies of SNF casks will be installed in these pipes and experiments will be conducted to assess the feasibility of cutting off the upper end of a cask, removing its top plug, cleaning the cask's top section, draining water from the cask, targeting and gripping spent fuel assemblies, and unloading the assemblies, including cases when the cask in its storage cell or the cell itself stands at one angle or another.

Comments and suggestions from the experts

Expert Bellona has been in contact with propose a different solution.

The main difference between proposal by the experts and the method proposed by Rosatom is that SNF is unloaded in storage in dry storage tanks cask by cask – and not assembly by assembly.

This would first of all expedite the extraction process by at least four or five times, and, secondly, would not lead to such severe consequences of radiation exposure as the assembly-by-assembly method will entail. Finally, the cask-by-cask approach would not require such huge investments as are needed now.

As regards the risk of occurrence of a spontaneous chain reaction, representatives of the nuclear industry themselves say the probability of such an occurrence is insignificant. Besides, there are ways to prevent a self-sustaining chain reaction when unloading SNF from the dry storage tanks. But even if a "neutron flash" does take place – as it has before – then the consequences of this will not be "nuclear," but those of radiation danger. That is, the consequences will be those of compromised radiation safety in the vicinity of the dry storage facility in Andreyeva Bay, which has occurred before, but there will in any case be no effects such as caused by the explosion of a nuclear bomb. Yet, a "neutron flash" is still an extreme occurrence that there are no failsafe ways to guarantee against – whichever methods or strategies are chosen for the retrieval of the SNF in storage, be it assembly by assembly or cask by cask.

This scenario envisions solving the following primary technical and organizational issues in preparation to SNF extraction:

- Giving adequate training to the personnel – specifically, those who will work with lifting equipment;
- Arranging guaranteed radiation protection for all personnel at all stages of the works; providing the personnel with individual means of protection, including hazard suits with closed respiration circuits;
- Carrying out a series of measures to prepare the tanks for SNF casks extraction, such as draining the water, removing extraneous objects, etc.;
- Installing a local ventilation system to provide for efficient air decontamination in the area surrounding the dry storage tanks; taking actions, as part of this measure, to ensure against the spread of radioactive dust both inside the tanks and outside them.
- Manufacturing – if the need arises to extract assemblies one by one – special equipment to be used to cut off the plugs on those casks that will resist opening.
- Designing and manufacturing an assortment of gripping devices that could be used when working with casks that have sustained damage to their upper ends.
- Providing for a technical solution for such situations when a cask needs to be held suspended over the storage cell, such as in cases when it becomes necessary to re-strap it or use a different grip, or if the top end of the cask needs to be mended to correct the damage it may have sustained.
- Providing television equipment for use by the personnel – first and foremost, for those who will work with lifting devices (cranes, hoisting winches, etc.)
- Developing technologies and equipment that could be used to perforate membranes on seven casks at a time, or else consecutively, as well as a device to ensure quick draining of radioactive water from the casks.
- Manufacturing a special container capable of holding seven casks.

The extraction operation starts with Tank 2B, since it holds the least number of damaged SNF casks.

The technology for extracting casks with SNF out of their storage cells would include the following stages:

- Lifting the cask out of its cell and securing it in a fixed position on the rim of the cell;
- Examining the cask, homing the grip on its top end using a special gauge, and pulling it up into the special (or primary) seven-seat container;
- Placing the primary container into the membrane-perforation and water-draining device;
- Perforating the membranes of the casks and draining water from them;
- Accommodating the casks permanently in the primary container and sealing the lower end of the container;
- Upon loading, transporting the container to the pier;
- Docking the special container to a TUK container using guiding equipment in place at the docking station;
- Reloading the casks into a TUK container for further transshipment onto the vessel and transportation by sea.

Measures should be taken while performing all of those tasks to ensure protection against personnel exposure and radioactive contamination of the surrounding environment (including decontamination of the equipment in use, air ventilation, etc).

This technology is not provided in extensive detail here, but if necessary, it will be easy to do, looking back on the experince gained while loading the SNF into their cells in the dry storage tanks.

Conclusion

A unique and extremely painstaking task is in store in the near future – extracting almost 23,000 spent nuclear fuel assemblies out of the storage cells of the dry storage facility at the former naval base of Andreyeva Bay. The uniqueness of this operation does not come into question – no one has ever attempted an endeavor like this before.

It now hardly remains a secret that many years ago, when the dry storage facility had been built, it was the result of sloppy workmanship, a structure put hastily together by military construction workers in the severe conditions of the Arctic north and following the cues of a slapdash project done unprofessionally and with egregious errors. Undoubtedly, this has contributed to the deplorable condition that the site is in today, in year 2009.

These are just some of the factors that will exacerbate the many difficulties associated with the already grueling operation that lies ahead:

- The world can offer no experience in organizing or performing works of such caliber; no personnel are qualified or experienced enough to cope with the task at hand;
- A multitude of uncertainties and risks plague the project that no one today can fully appreciate or take precautions against;
- The work will have to be carried out throughout a lengthy period of time in severe Arctic conditions;
- None of the personnel who had taken part in the liquidation of the accident in Building 5 or those who had loaded the last of the SNF into the dry storage tanks were invited to share their expertise and knowledge of the situation at the stages of assessing the conditions at the dry storage facility and developing the SNF removal project. Their experience, however, would have been invaluable for the preparation of the project and may yet prove indispensable when the extraction operation goes under way;
- A fully automated retrieval process has its own very significant drawbacks, such as described above. It is furthermore known that the less human participation there is in a process the lesser the reliability of the entire complex will be. It looks like a most evident likelihood that it will be impossible to avoid human interference into an extraction process planned, as it is, to be carried out with machinery only. This means that no one will be able to rule out completely the risk of radiation exposure for the personnel.

Despite that the main concept of the future SNF extraction operation is based on an SFA-by-SFA extraction strategy, all of the defective fuel – spent fuel assemblies that will prove to have stuck in their casks or whose fuel-containing sections have been torn or damaged, with fuel spilled out of the assemblies – will have to be removed cask by cask. According to Rosatom's information, surveys conducted in Andreyeva Bay confirm the conclusion that if at least one spent fuel assembly is safely pulled out of its cask, the remaining assemblies in the cask can be extracted with the cask with no foreseeable risks involved. Even if the bottom of the cask comes loose then and the SFAs fall back into the storage cell, there is no risk of a spontaneous chain reaction.

At the very least, there was the option of a combined extraction method that could have been taken as the basis for the future operation. This method would have fastened the procedure as, first, just one SFA could be unloaded from a cask and then the remaining assemblies could be taken out together with their storage cask. In this case, there would have been no risk of a spontaneous chain reaction, but the retrieval operation could be expedited substantially.

When all of this is over we will hopefully finally know if the right path was chosen to break free from the Andreyeva Bay quagmire.

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