Intermediate Results and Prospects for Handling the Bilibino NPP Spent Fuel

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Introduction

The policy of the Rosatom State Corporation in the field of spent nuclear fuel (SNF) management according to the industry Concept on SNF Management (2008) is based on the main principle that is the need for SNF reprocessing to ensure the environmentally compatible fission products handling and reuse of regenerated nuclear materials in the nuclear fuel cycle. Moreover, this Concept states to apply the technological schemes based on the SNF storage followed with reprocessing for all types of NPP spent fuel. This approach formed the basis for the Program on Development of the SNF Infrastructure and Management in 2012-2020 and for the period up to 2030 approved in November 2011.

The only SNF that fits none of handling schemes are spent fuel assemblies (SFAs) from the Bilibino NPP. Its design provides neither technological scheme for SNF removal from the power units nor procedure and transport equipment for SFAs transportation within the site and removal from the NPP. The main fuel handling option is its long-term dry storage at the NPP site in existing storage pools.

Since SNF of the EGP-6 reactor facility is long-length and its fuel composition is similar to one of AMB fuel modifications, this type of SNF can be reprocessed at Mayak PA as soon as the cutting and encapsulating division will be put in operation, i.e. after 2016. But large distance to the Bilibino NPP, absence of infrastructure for SNF withdrawal, preparation and removal from the site as well as absence of appropriate transport infrastructure in the area of the NPP location make this project implementation extremely expensive. The options for the SNF shipment from the Bilibino NPP to reprocessing by sea or air were assessed under the Federal Target Program on Nuclear and Radiation Safety Assurance.

However the permafrost in the area of the Bilibino NPP location favors building the RAW and SNF ultimate disposal facility with either wells or tunnels. In 2012 the Work Group including the representatives from the Rosatom State Corporation, the Chukotka administration, the nuclear industry organizations that have developed the EGP SNF transport and handling schemes and the Rostechnadzor expert organization (Scientific and Engineering Centre for Nuclear and Radiation Safety) shall make a choice of the optimum option for EGP SNF management on the results of the comprehensive analysis.

Removal of spent nuclear fuel from the central hall

Under the existing technology, SFAs are discharged from the reactor and loaded into the canisters. Then the canisters are placed into the storage pool. A facility that was initially planned for storing and handling the SFAs has not been constructed. Instead of this, a compact storage was applied, i.e. the canisters were placed close to each other and bound together in the storage pool.

At the beginning of the NPP operation the canisters were made of carbon steel. They were coated with coal enamel to retard corrosion, but it was impossible to assure that the canisters would retain integrity during long-term storage in hot water of the storage pool. Moreover, there was a corrosion hazard to the pool walls. So two storage pools were drained out, and since then the spent fuel is in dry storages.

Now two drained pools at the Bilibino NPP contain SFAs placed close to each other and bounded together with wire and textile ribbon (Fig. 1). Some canisters containing SFAs are located in the hard-to-reach pool bays.

Fig. 1. Layout of SFAs in the drained storage pool

The condition of canisters and walls in the drained storage pool is unknown, because it is impossible to enter it and is undesired to flood it with water. A complex engineering examination was performed to find out if it is possible to remove all SFAs from the drained storage pools. The examination was carried out using the unique specifically developed equipment. After the examination it became possible to develop the technology and equipment for the SNF removal from the reactor building.

A special manipulator-grapple was developed for removal of the SFA canisters from the drained pools, which is placed in the existing openings in the pool plates and then its arm is moved into the working position (Fig. 2). The main difficulty in the development of this manipulator was to achieve the required lifting capacity with the rigid restrictions of the design size and a significant boom reach for operations in the bays. Besides, other equipment, for example, for cutting canisters and SFA encapsulation was designed (Fig. 3). The functionality of the manipulator and other equipment items was demonstrated at the experimental facility at the Sosny premises in the presence of the representatives of the Rosatom State Corporation and Rosenergoatom Concern.

By the time of the NPP shutdown, two more storage pools will be filled up and the SFAs in these pools will be stored in water. The unloading technology is available now.

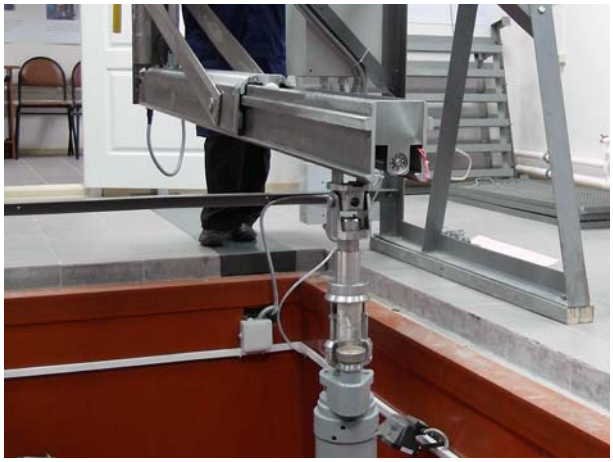

Fig. 2. Prototype manipulator for removal of the SFA canisters from the storage pool

Fig. 3. Prototype facility for cutting canisters and SFA encapsulation

Consequently, the technology for removal of all spent fuel from the central hall is available. The feasibility of the adopted solutions has been tested in the experimental facility. The safety of works complies with the regulatory requirements with respect to the seismic hazard of the NPP site (preliminary safety analysis report was prepared and agreed with the SSC IPPE being the scientific leader of the NPP). This technology will be in demand for any option of spent fuel handling at the Bilibino NPP.

Spent fuel handling beyond the reactor

While the final decision about the SNF stored at the Bilibino NPP is not taken, it is unreasonable to study thoroughly the equipment. Thus the feasibility study was made to estimate the cost of the work, including the fabrication of the equipment. The following options were considered:

1) further storage of SFAs in the storage pools;
2) disposal into the neighboring wells or tunnels;
3) removal for reprocessing or storage.

Let’s consider these options in detail.

1) Storage of SFAs in storage pools

Based on the results of the feasibility study made by the Siberian Chemical Plant in 2009-2010 for storage of SFAs in the storage pool (in the gas environment or embedded in concrete), the safety can be ensured for the next 50 years. The expenses for the preparation and maintenance of the safe storage for a 50-year period were estimated at 70 billion rubles (according to the prices of 2009). In addition to the high cost there is another essential shortcoming of this approach: storage of SFAs in the storage pool is a delayed decision, i.e. it is a source of potential hazard in the region and does not solve the problem of the NPP decommissioning. Therefore, no later than in 50 years the problem will have to be solved.

2) Disposal of SFAs

To assess the possibility of building the experimental and production facility for the RAW and SNF underground disposal within the Bilibino NPP site the VNIPIpromtechnology has performed the feasibility study and the environment

impact assessment providing the comprehensive analysis of SNF disposal in a well-type or tunnel-type repository. The permafrost typical for the Bilibino NPP site provides favorable conditions for the RAW and SNF ultimate disposal, such as:

– absence of water in liquid state in the accommodating geological environment prevents any migration of the radionuclides from the disposal facility to the environment;
– slowdown the oxidation-reduction reactions in the permafrost extends the functionality of engineering barriers;
– natural cold is a natural thermal barrier;
– usual life time of the thawed zone is tens of years;
– subsequent freezing of the total repository volume and recovery of average permafrost temperatures;
– functionality of engineering barriers ensures the containment of the area of possible radionuclide spread off the repository volume within the thaw period; and
– geologic and permafrost conditions in the area of the Bilibino NPP location agree with the concept for RAW and SNF disposal in the permafrost.

Within the environment impact assessment the VNIPIpromtechnology analyzed all safety requirements (nuclear and radiation safety, radionuclide migration). The estimated level of beyond design accidents is 10^{-7} that is less than the level of negligible risk.

But the weakest spot of the permafrost disposal concept are poor arguments confirming the constant permafrost within the period necessary for long-term SNF repository.

3) SFA removal

The SFA removal to the mainland is realizable. Since the heavy components (reactor vessels, steel pools plates, etc.) were delivered to Bilibino by the Northern Sea Route, the TUK casks can be removed by the same route. The removal can also be performed using a heavy cargo aircraft, such as AN-124-100. This option was substantiated by the feasibility study carried out by the Sosny Company in 2010-2011. Shipment of TUK casks with SNF for reprocessing is considered below.

Conveyances

All cargos are delivered to the Bilibino NPP either by sea or air and in both cases the trucks are used. The same modes are applicable to the SNF removal (Fig. 4).

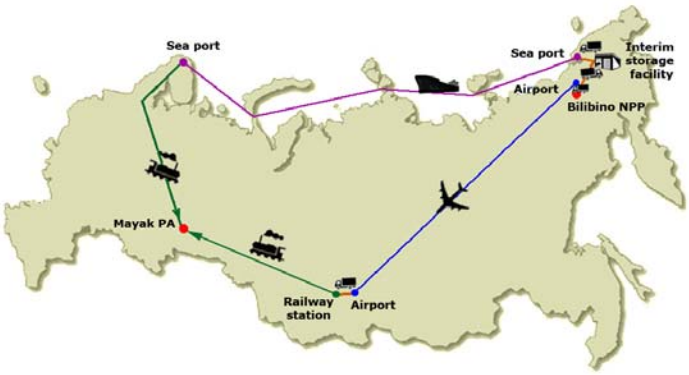

Fig. 4. Possible routes of SNF removal from the Bilibino NPP

The sea route: by truck along the winter road from Bilibino to the temporary storage near the port and then in the summer shipping season by sea to the port on the mainland and then by railway to the destination point. The TUK casks are transported back in the reverse sequence. Each of the road sections can be used four months a year, and the cycle of transportation, including the return of empty casks, takes for about two years. The regularity of the heavy vehicle traffic by the winter road much depends on the weather. The possibility of transportation by the Northern Sea Route also depends on the weather conditions, which are very changeable in this region. Nevertheless, the traffic by the winter road is arranged every season, and three sea voyages are possible in the navigation period to the European part of Russia and back, provided that they are escorted by icebreakers. The complete SNF removal from the Bilibino NPP by sea costs about 50 billion rubles and includes production and delivery of the equipment, construction work, equipment assembling, work performance, organization of the necessary transport infrastructure, SNF shipment and reprocessing at Mayak PA.

The air route: transportation by air from the nearest airport to the airport near the railway and then by train to the destination point. The possible options are: either to use the local airport, where the aircrafts with a carrying capacity of up to 20 tons can land and take off a year-round or upgrade the runway that would make it possible to use an aircraft with a cargo carrying capacity of up to 100 tons and thus significantly reduce the number of flights. The savings from the flight reduction are approximately equal to the cost of the runway upgrading. The cost of “air” option will depend on the applied

cask:

– Transportation of spent fuel in a *B(U) shipping cask* by air is possible provided that its content meets the requirements for the special form radioactive material. The cost of SNF removal from the Bilibino NPP in B(U) casks by air is estimated roughly at 70 billion rubles, of which 10 billion rubles will be spent on the local airport upgrade.

– Since the main requirement to *Type C shipping cask* is to maintain its properties in case of any air crash, the SNF shipment in Type C casks is safer than in Type B (U) ones. Moreover, the Type C cask has larger capacity. Now the RFNC-VNIITF performs the comprehensive analysis of the feasibility to remove the SNF from the Bilibino NPP in Type C casks under the contract under the Federal Target Program on Nuclear and Radiation Safety. This option is roughly estimated at 40 billion rubles.

Destination points

At the Mayak PA, being the unique reprocessing plant in Russia, all SNF is divided into two categories: reprocessible and non-reprocessible. For the present the spent fuel from the EGP-6 reactor facility is considered non-reprocessible but since it is similar to one of AMB fuel types to its fuel composition it can be reprocessed at Mayak PA as soon as the cutting and encapsulation division is put in operation and the plant transport infrastructure is upgraded. The reprocessing cost was estimated and included in the above amounts. It is planned that the AMB spent fuel will be reprocessed at existing facilities till 2023 that is in good agreement with the work plan to start the activities at the Bilibino NPP in 2022.

Assessment of work schedule

At present the Rosatom State Corporation has taken the Decision on period of shutdown of Bilibino NPP power units Nos. 1-4 for decommissioning:

– power unit No. 1 – 2018; and

– power units Nos. 2, 3 and 4 – 2019.

When the Bilibino NPP reactors are shut down, the spent fuel that has been accumulated for the NPP operation period since 1974, will become an acute problem. It is too expensive to maintain the reactor in the shutdown condition for a long time. Putting the reactor in dead storage in the Far North will be even more expensive, as it will be necessary to maintain the main infrastructure. The qualified personnel competent in design and reactor operating history will leave the plant and by the beginning of the decommissioning activities it will be necessary to employ and train the new staff and build new residential and production buildings.

Due to the high storage pool capacity and low NPP power, it is expected that in the existing operating conditions the storage pools will be filled in ten years that is a natural limitation of the NPP service life. But before the activities on SFAs removal from the central hall starts immediately after shutting down the last of the four reactors it will be necessary to deliver and mount all the equipment required for the removal of the SFA from the central hall by 2022. The estimate period of preliminary activities including the design, state expert assessments, front-end engineering, equipment improvement and adjustment at the mainland, equipment delivery to the NPP and personnel training is more than ten years.

The preparation activities for SNF unloading from the storage pools at the Bilibino NPP are carried out as part of the Federal Target Program since 2009. At present the feasibility studies in various areas and some design work have been completed. The large work is to follow.

Assessments and ways to reduce risks for different options of spent fuel handling

To make the final decision on the Bilibino NPP spent fuel it is necessary to assess the risks arising in the standard handling and hypothetical accident conditions taking into account the severity and probability of their occurrence. In 2012 under the Federal Target Program the Sosny Company experts prepare the assessment of radiation risk to the personnel and the public for various options of shipment of the spent fuel of EGP-6 reactor facility from the Bilibino NPP to Mayak PA for reprocessing.

Conclusion

In 2012 the Rosatom State Corporation shall make the comprehensively substantiated choice of the option of EGP spent fuel handling with due regard to the recommendations of the Work Group including the representatives of the Rosatom State Corporation, the Chukotka administration, the nuclear industry organizations that have developed the EGP SNF transport and handling schemes and the Rostechnadzor expert organization (Scientific and Engineering Centre for Nuclear and Radiation Safety).