PREPARATION FOR THE FUTURE SPENT FUEL TRANSPORTATION AND DISPOSAL AT LOVIISA NPP

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Abstract

Spent fuel disposal in Finland is in the phase where Posiva is preparing for construction of the encapsulation plant and spent fuel disposal tunnels, and later submitting the operating license application. As part of the preparations, Posiva is planning the future operating phase of the spent fuel encapsulation and final disposal facility. The original operating plan has been to dispose of fuel from both Olkiluoto and Loviisa NPPs in parallel starting around 2024. Another option is to start disposing fuel from Olkiluto NPP first, and continue with Loviisa NPP fuel later. Whatever production option is selected it requires actions and preparations at Loviisa NPP. This paper presents some of these actions.

1. INTRODUCTION

Loviisa NPP consists of two Russian design VVER-440 type PWRs. Loviisa 1 unit started operation in 1977 and Loviisa 2 unit in 1980. The current operating licence is valid until 2027 (Loviisa 1) and 2030 (Loviisa 2) i.e for 50 years of operation. Loviisa NPP site has all infrastructure needed for treatment and disposal of the operational waste from the two plant units, as well as for storing the spent fuel. Originally all spent fuel was transported back to Russia (Soviet Union) but this was terminated in 1994 by law before Finland joined the European Union. The law prohibits import and export of all radioactive waste and spent fuel.

After the law a new solution was needed for the spent fuel from Loviisa NPP. As a solution for this Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (Fortum) established a joint company Posiva, which is dedicated for the research and development as well as implementation of spent fuel disposal of the owners. Posiva started operation in 1995, but it's work is based on the previous work done at TVO and IVO companies since the early 1980's.

The main principles of radioactive waste management in Finland were fixed in government's decision in principle (DiP) from 1980. In this document, the main option for spent fuel management was to send it abroad for reprocessing, without taking back the waste. The direct disposal of the spent fuel to Finland was the second option. DiP determined also the overall time schedule for spent fuel management in Finland, for example, specifying that the site for spent fuel repository shall be selected by 2000, and the construction licence application for it shall be left by 2010. The target year for starting operation of the spent fuel disposal plant was around 2020. Posiva and its owners have successfully followed this government's DiP and hold the original schedule. The ultimate goal was to start disposing spent fuel around 2020 but the current schedule indicates that Posiva could start disposing the fuel around 2025. See Fig. 1 for the main milestones during the last 40 years in spent fuel management in Finland.

This paper presents briefly the status of Posiva's work today, shows the transport options for spent fuel from Loviisa NPP to Olkiluoto site, where Posiva's disposal facility is located. The paper also present examples of preparatory work at Loviisa NPP for the future spent fuel disposal, and the status of the spent fuel storage at Loviisa NPP and options for increasing the storage capacity there. The impact of decay heat on spent fuel disposal schedule is also discussed.

2. ORIGINALITY, COPYRIGHT AND PUBLICATION

The text submitted is original and has not been published as such elsewhere previously.

3. STATUS OF POSIVAS WORK

Preparation for spent fuel disposal started already 40 years ago as Finnish Government made a decision in principle on the schedule, reporting and program for spent fuel disposal. The original strategy was to send spent fuel abroad for reprocessing and final disposal of spent fuel to the Finnish bedrock was only secondary option. The main milestones of the program are illustrated in Fig. 1, including the ratification of the site selection decision in the parliament 2001, and the construction license granted November 2015. The main milestone in the coming years are the construction license application early 2020's and start of operation around 2024.

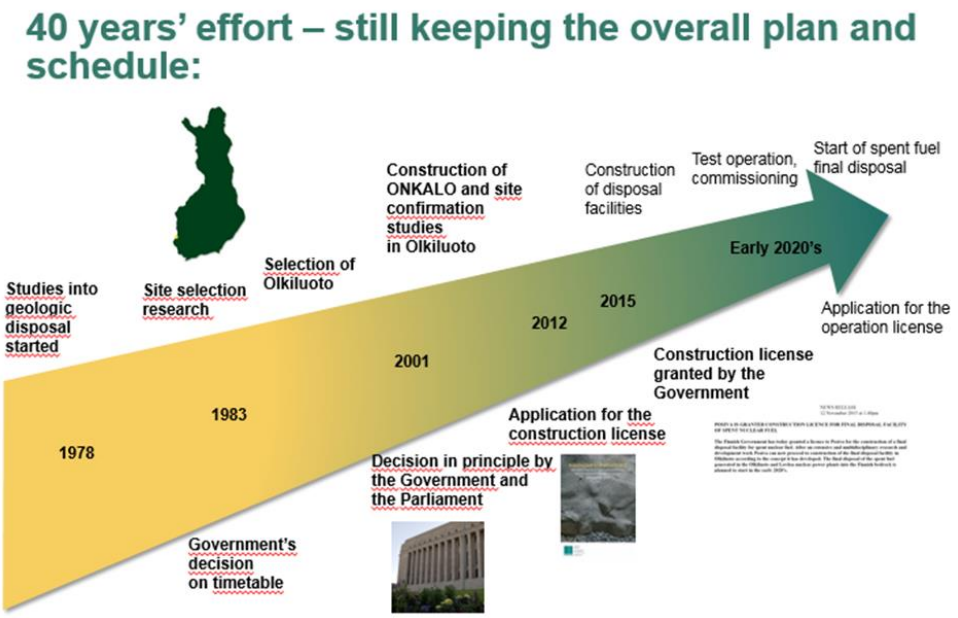

FIG. 1. Milestones during the first 40 years of spent fuel disposal preparation [1].

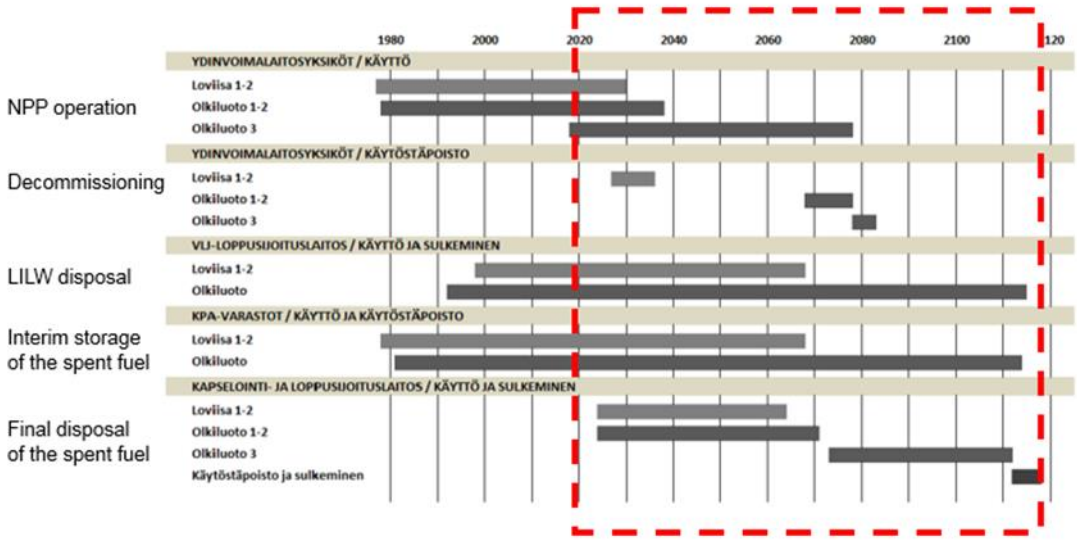

FIG. 2. The principle schedule of radioactive waste management of Olkiluoto and Loviisa NPPs [2].

Posiva and its owners have spent 40 years for preparing the spent fuel disposal. The operating NPPs in Olkiluoto and Loviisa Finland still have at least 10 to 20 years operational life left. Prolongation of the operational life of the existing NPP units is still possible, if it is considered feasible from financial and technical point of view. Taking care of the spent fuel from the existing operating plants will take at least another 40 to 50 years to be completed. See Fig, 2 for the overall schedule of radioactive waste management in Finland [2], and the remaining tasks inside a red box. The disposal of Olkiluoto 3 plant spent fuel will continue until early 2100's.

One important milestone in Posiva's programme was reached in 2018, when Posiva completed the Full Scale In Situ System Test (FISST), where two copper canisters with electric heaters were disposed of to a test tunnel in ONKALOTM. See Fig. 3 for the test configuration. The FISST -test used full-scale prototype equipment and it was done according to the same instructions and procedures as the operation will be done. It includes all the same buffer, backfilling and closure components as the real concept. The main aim of FISST is to ensure that the installation process of copper canisters works as planned in the real underground environment, including the backfilling and closure of the disposal tunnels. The test will be monitored after closure with around 500 instruments and it will continue for several years. The main focus in the test was the installation process, but the test also provides information about the conditions in the tunnel after closure. [3]

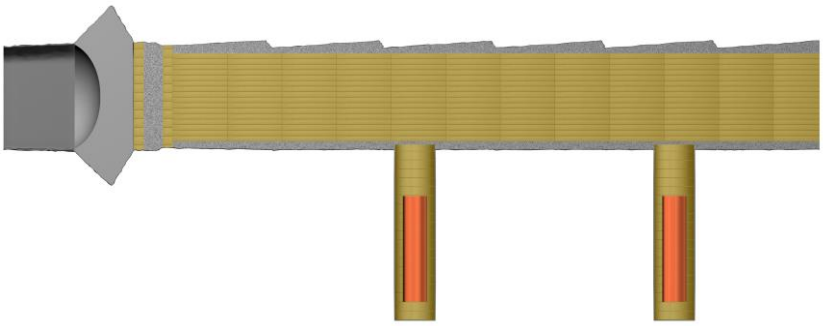

FIG. 3. FISST test configuration at ONKALO™ [1].

4. TRANSPORT OPTIONS FOR SPENT FUEL

During the early operation years of Loviisa NPP, spent fuel was transported from Loviisa NPP to Russia by rail. These operations continued successfully until the government changed the law and export of spent fuel was no more possible. All together 2823 spent fuel assemblies were successfully transported to Russia without any challenges. Transport by rail is still an option for Loviisa spent fuel, but it would require transport of spent fuel by road from the NPP to the Loviisa railway station, and later also another road transport at Olkiluoto side.

The transportation of spent fuel from Loviisa to Olkiluoto is planned to be performed as road transportation, but railroad and ship transportation and a combination of these three have also been examined as optional transportation methods. There is a great deal of experience on the safety of transportation of spent nuclear fuel in Europe as well as in Finland. Spent nuclear fuel has been transported from power plant units to interim storage facilities at the power plant sites, and, during the period from 1981 to 1996, it has also been exported from Loviisa to Russia (or the Soviet Union). As Olkiluoto in the municipality of Eurajoki has been selected as the final disposal site, there is no need for long-distance transportation of the fuel from the Olkiluoto NPP. This is not the case for the fuel from Loviisa NPP, which has to be transported from Loviisa NPP from Hästholmen in the town of Loviisa in the south coast of Finland to the Olkiluoto site. The distance between Loviisa NPP and Olkiluoto is about 340 to 370 kilometres, depending on the route. The total annual required number of transports from Loviisa to Olkiluoto is about four.

The infrastructures used in Loviisa for packing fuel to the transport casks in 1990's still exists. Similar procedures will be used in the future transportations, if possible. However, the transport casks used that time are out-of-date. As an option, a conceptual plan has been made of a new spent fuel packaging station, to be built adjacent to the spent fuel storage. The planning of future packaging continues including also analysis of methods for packaging leaking fuel rods. This information is needed already for the operating license application of Posiva spent fuel encapsulation and final disposal facility.

5. STATUS OF THE SPENT FUEL STORAGE AT LOVIISA NPP

5.1. KPA storage at Loviisa

The original capacity of the spent fuel storage at Loviisa NPP was only for 3 years, because of spent fuel return to Russia. In 1984, a new storage (3 pools) was constructed to allow 5+ years cooling of the fuel before transportation.

Storage capacity increases after spent fuel transportations to Russia have been made in several phases. In 1999 four more pools with open racks were constructed, which increased the capacity up to 2010. Starting from 2007, open racks have been converted to high density racks as needed. With high density racks the storage capacity can be added when needed and there will be enough capacity until early 2030's i.e over the current operating life of the plant. If the operation continues after 2030, furthermore high-density racks can be installed. Use of dry storage alternative is also an option, as well as construction of additional pools to the storage.

The current capacity of the spent fuel storage is 6200 positions from which 5400 is used. A part of the capacity is needed for potential evacuation of the pools, in case of e.g leakage of the liner of the pools. Reactor pressure vessel shielding elements, which are used in Loviisa NPP in the outer part of the core to protect the reactor pressure vessel against neutron radiation, take a part of the storage capacity.

After the power production at Loviisa NPP ends the spent fuel storage will be made independent. This means that it will be disconnected from the power plant processes, new systems for e.g treatment of pool water and cooling the pools will be constructed, and the storage continues operating independently as long as all spent fuel has been transported to Olkiluoto for final disposal. According to the current schedule, the independent operation of the storage will continue until 2060s after which it will be dismantled.

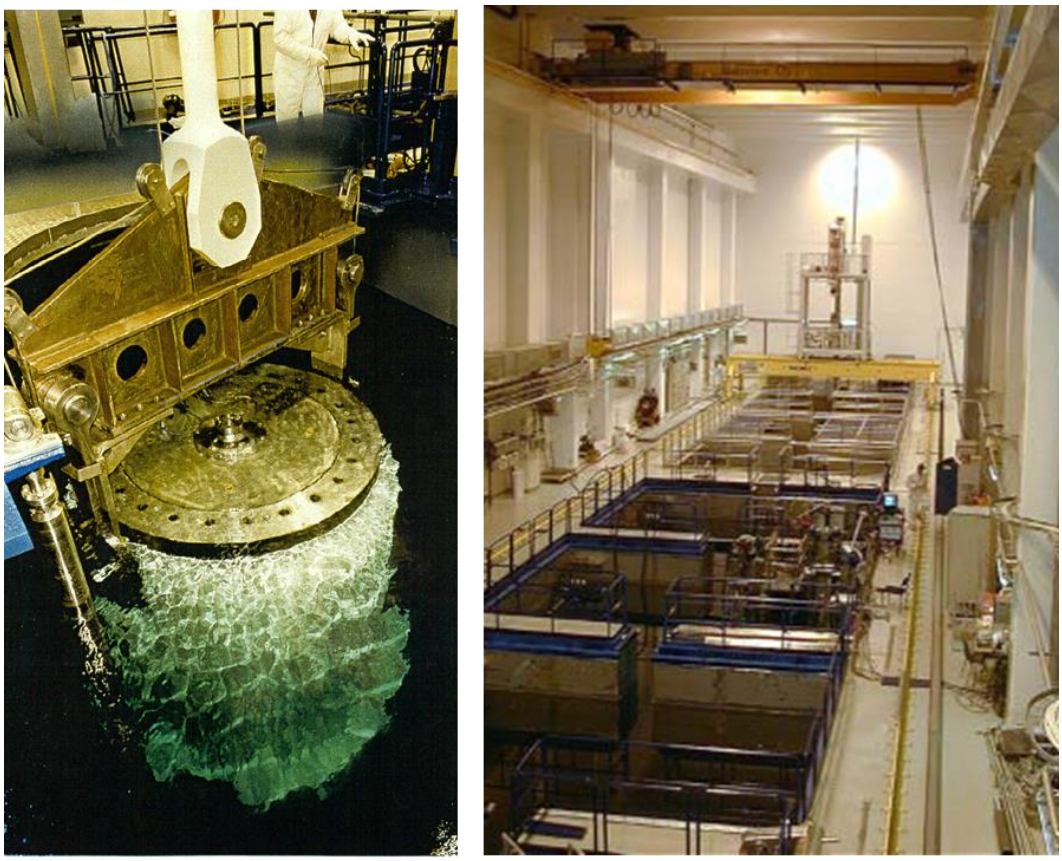

FIG. 4. Spent fuel transport cask and spent fuel storage at Loviisa NPP.

5.2. KPA-programme

In 2015 it was decided in Loviisa NPP to start an internal programme on preparation for spent fuel long term storage, packaging and transport at Loviisa NPP. The program gathers all development activities and projects related to spent fuel storage and packaging for transportation into a coordinated programme. In the first phase the main focus is in aging related issues, since the oldest part of the spent fuel storage has already reached its original design life (30 years). Later, when the time comes to start transporting fuel to Olkiluoto, the focus will be more on preparations for spent fuel packaging and transportation. Ensuring that enough storage capacity is available during the remaining operational life is also one major issue of the programme.

The current work include modernisation of the main crane of the storage, investigation of the status of the concrete structures of the storage and liners of the storage pools, and installation of new high density racks, as needed. In addition, a digital twin of the main crane of the storage will be made to be used in the simulations and training of lifting of high density racks. The aim is to be able to lift the racks in one piece to the pools in the future. The pool-side inspection equipment (ATULA), used in investigation of the spent fuel at the storage, will also be modernised.

In longer term the work will include modernisation of the fuel transfer machine and installation of additional high density racks. Study of capacity increase options of the spent fuel storage is also a part of the programme. In addition, all necessary equipment for loading fuel to transfer casks have to be available when transport operations begin. This includes either modernisation of existing infrastructure or building a new building for these operations.

6. IMPACT OF DECAY HEAT OF THE SPENT FUEL BUNDLES ON THE DISPOSAL SCHEDULE

One main factor affecting the schedule of spent fuel disposal is the decay power of the fuel. Posiva has determined that the maximum heat production of one Loviisa spent fuel canister (including 12 fuel bundles) is 1370 W. If we look at all the spent fuel which will be produced at Loviisa NPP during 50 years of operation (excluding those bundles transported to Russia) the average power of a rod bundle reaches this level around 2050. This means that it would be possible to dispose of all the fuel that year. In reality the disposal reception capacity is limiting the disposal operations, and the schedule has to be built around this year. For example starting disposal of fuel in 2044 means that all fuel can be disposed of by 2056.

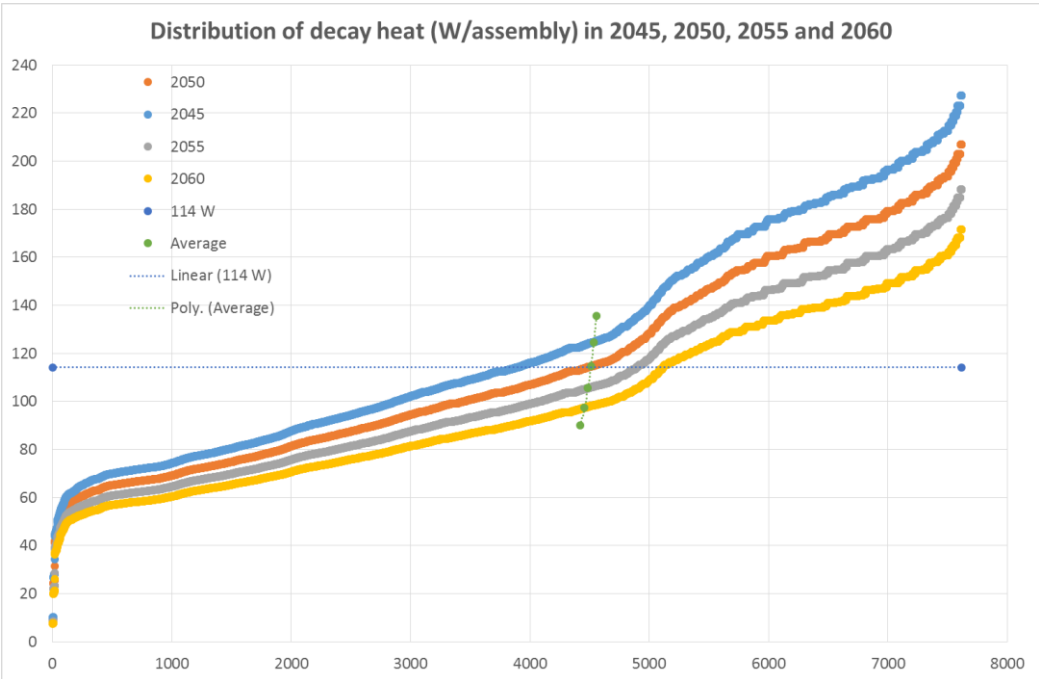

FIG. 5. Distribution of decay heat of the spent fuel of Loviisa NPP.

Selecting fuel to one package is an optimisation process. Kuopanportti and Lahtinen developed a tool for selecting the spent fuel bundles in an optimal way for the spent fuel canisters [4]. Their study utilized the mathematical optimization algorithms that were developed by Timo Ranta is his D.Sc. thesis at Tampere University of Technology, 2012 [4]. In the used formulation, the target of the optimization is to minimize the maximum canister-wise decay heat load at the time of the final disposal. A recent paper at AER symposium presents the results of their work [4]

The optimization algorithms were implemented using the Python programming language. Kuopanportti and Laitinen demonstrated, that, despite a huge amount of degrees of freedom, the algorithms of Ranta were capable of finding practically a global optimum for the problem of selecting fuel bundles for the disposal canisters [4]. The outcome of the work is a software tool, which can be used for further final disposal analyses according to various needs. It also supports the planning of future fuel transfer operations at the spent fuel storage as part of the preparation for future packaging of the fuel to transfer cask.

7. SUMMARY AND CONCLUSIONS

The spent fuel disposal programme in Finland has continued for 40 years and followed well the original schedule. The spent fuel encapsulation and final disposal facility has got the construction license and preparations for the operating phase are under way. The spent fuel disposal operations are expected to start around 2024.

The main focus of the preparations at Loviisa NPP in on the aging related issues of the spent fuel storage. The capacity of the storage can be increased using high density racks. In the longer run, also dry storage option and construction of additional pools are possible, if needed. With these there will be enough storage capacity for all fuel coming during the current or prolonged operating life of Loviisa NPP.

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