THE SPENT FUEL MANAGEMENT IN FINLAND AND MODIFICATIONS OF SPENT FUEL STORAGE

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Abstract

The objective of this presentation is to share the Finnish regulator's (STUK) experiences on regulatory oversight of the enlargement of a spent fuel interim storage. An overview of the current situation of spent fuel management in Finland will also be given. In addition, the planned modifications and requirements set for spent fuel storages due to the Fukushima accident are discussed.

In Finland, there are four operating reactors, one under construction and two reactors that have a Council of State's Decision-in-Principle to proceed with the planning and licensing of a new reactor.

In Olkiluoto, the two operating ASEA-Atom BWR units and the Areva EPR under construction have a shared interim storage for the spent fuel. The storage was designed and constructed in 1980's. The option for enlarging the storage was foreseen in the original design.

Considering three operating units to produce their spent fuel and the final disposal to begin in 2022, extra space in the spent fuel storage is estimated to be needed in around 2014. The operator decided to double the number of the spent fuel pools of the storage and the construction began in 2010. The capacity of the enlarged spent fuel storage is considered to be sufficient for the three Olkiluoto units.

The enlargement of the interim storage was included in Olkiluoto NPP 1&2 operating license. The licensing of the enlargement was conducted as a major plant modification. The operator needed the approval from STUK to conduct the enlargement. Prior to the construction of this modification, the operator was required to submit the similar documentation as needed for applying for the construction license of a nuclear facility.

When conducting changes in an old nuclear facility, the new safety requirements have to be followed. The major challenge in the designing the enlargement of the spent fuel storage was to modify it to withstand a large airplane crash. The operator chose to cover the pools with protecting slabs and also to build a landfill embankment and concrete structures outside the storage. The designing of the cover slab structures is an optimisation task between safety issues that are partly opposite to each other.

The construction phase of the enlargement caused some unexpected events. Synchronization of the construction phases with implementation of modifications in systems already in use in the original facility proved out to be more challenging than was originally considered.

The construction license application of the spent fuel encapsulation plant and the underground disposal facility was submitted at the end of 2012. These facilities are considered to receive the spent fuel also from Loviisa NPP. Operation of the final disposal units is estimated to begin in 2022.

1. An overview of the spent fuel management in Finland

In Finland, there are four operating reactors, one under the construction and two reactors that have a Council of State's Decision-in-Principle to proceed with the planning and licensing of a new reactor. The first nuclear power plant (NPP) units owned by Fortum Power and Heat Oyj (Fortum) were built in Loviisa in South-Eastern Finland on the coast of the Gulf of Finland. They began commercial operation at 1977 and 1980. The Loviisa reactor units are soviet design VVER-440 PWR reactors. In Olkiluoto, there are two operating ASEA-Atom BWR units and an Areva EPR under construction. The BWR units began their operation in 1978 and 1980. The Olkiluoto NPP units are owned by Teollisuuden Voima Oyj (TVO). TVO also has a Decision-in-Principle to construct a fourth reactor unit in Olkiluoto. Fennovoima is a newcomer the Finnish in nuclear energy sector. Fennovoima has a Counsil of State's Decision-in-Principle to proceed with the planning and licensing of a new reactor unit in Hanhikivi, Pyhäjoki. The site is situated in Northern Ostrobothia, on the coast of the Bothnian Bay.

The spent fuel from Loviisa NPP units was transported to the Soviet Union for reprocessing until 1996. Since then, the spent fuel of the two Loviisa units has been stored in a spent fuel interim storage.

In Olkiluoto, all the spent fuel of the two operating reactors has been stored in the spent fuel interim storage after being cooled enough in the fuel pools of reactor units. The interim storage is soon going to be full of the spent fuel from OL 1&2 units. Considering that the OL 1&2 have some decades of operating time left and the OL3 unit to start its operation in the future, more space for the spent fuel is needed at the interim storage. The final disposal of the spent fuel is planned to begin in 2022. These aspects set the boundary conditions for the amount of extra space needed at the interim storage. TVO, the operator in Olkiluoto NPP site, decided to double the number of the spent fuel storage pools to have six pools altogether after the enlargement. This enlargement project of will be discussed later in this paper.

Posiva Oy is the company responsible for the final disposal of spent nuclear fuel of its owners. The owners are the two operating nuclear power companies Fortum and TVO. The final disposal of spent nuclear fuel is planned to begin in 2022. Posiva has submitted an application for the construction license of the encapsulation plant and the final disposal facility in the end of 2012. In the encapsulation plant the spent fuel bundles are packed in cast-iron-copper canisters. Packed canisters are then transferred from the encapsulation plant to the underground disposal facility to be disposed in deposition holes.

The Decision-in-Principle of Fennovoima is valid until 2015 and it has to apply for a construction license before that. In the construction license application, Fennovoima has to present a plan about the spent fuel disposal. The options for Fennovoima are to co-operate with existing power companies or to design its own final disposal facility.

2. Regulator's experiences of supervising the enlargement of a spent fuel interim storage

In Olkiluoto, the operator TVO is enlarging the spent fuel interim storage. The enlargement of the interim storage was included in Olkiluoto NPP 1&2 operational license. The licensing of the enlargement project is conducted as a major plant modification. Prior to the construction of this modification, the operator was required to submit to STUK as detailed documentation as needed for applying for the construction license of a new nuclear facility.

Originally, the spent fuel interim storage had three storage pools in a row. The enlargement of the storage consists of three new pools. Thus, after the enlargement, there will be six pools in a row.

The original spent fuel storage was commissioned in 1988. When conducting changes in an old nuclear facility, the new safety requirements have to be followed. The major challenge in designing the enlargement was to modify it to withstand a large airplane crash (APC). The operator designed a landfill

embankment and concrete structures outside the interim storage. These structures will protect the fuel pools from direct impact in case of APC. The fuel pools are covered with cover slabs to prevent damaging of the fuel by falling debris or facility structures caused by the APC.

The designing of cover slab structures is an optimisation task between the safety issues that are partly opposite to each other. The cover slabs for the spent fuel pools are dimensioned to be light enough to ease the handling but strong enough to withstand the impacts followed by APC to the storage building.

The embankment is dimensioned to be high enough to protect the pool structures from the direct airplane impact. The material of the embankment is compacted but still loose enough not to form sharp and heavy pieces at the airplane impact.

The acceptability of the solutions that the licensee presents to meet the regulatory requirements is not always obvious. In many cases the licensee has presented many options to meet the criteria and has then chosen the most suitable one considering all the aspects. To evaluate the acceptability of the chosen solutions comparing and experimental analysis is often needed.

3. Safety of the operating spent fuel storage during enlarging constructions

Protective structures

The enlargement of the operating spent fuel interim storage is a challenging task. The safety of the stored spent fuel has to be taken into account in every phase when conducting the enlarging activities such as construction work at the vicinity of spent fuel pools and implementing system modifications.

The construction of the enlargement is implemented in several stages. First, all the structures of the new pools were constructed outside the existing storage building. After all the new structures were completed, the new and the existing parts of the building are to be integrated. Before this phase, the end wall of the existing storage building has to be pulled down to form a single continuous space for the existing and the new pool rooms.

The end wall of the existing part of the storage building is a boundary of the radiation protection monitoring area. Therefore, before pulling it down, the pools of the existing storage had to be protected from the construction activities. The furthermost pool of the three existing pools was empty of spent fuel and water. This pool was reserved to be an evacuation pool of the original storage facility. The evacuation pool was covered by hollow-core slabs to protect the pool from building activities. The hollow slabs also formed a working surface for construction of the temporary protective element wall. The middle pool beside the evacuation pool was filled up to its maximum capacity of spent fuel. The middle pool was also covered to protect the spent fuel from the construction works done in the vicinity. The cover of the middle pool was made of light structured sandwich elements: a core of mineral wool with steel sheets.

The temporary protective element wall was built between the evacuation pool and the middle pool to replace the end wall as a boundary of monitoring area. The temporary wall was also built of sandwich panel elements and supported by steel structures. The temporary wall was dimensioned to withstand the underpressure from the inside of the building and to meet the leak tightness requirements.

Scheduling of the enlargement project phases

The phases of the enlargement have to be carefully planned not to disturb the operation, or risk the safety of spent fuel storage, when enlarging the systems and structures of the spent fuel storage. In the OL spent fuel storage, the exhaust air ventilation fans of radiation monitoring area were changed to larger ones in an early phase of the enlargement project. The new fans were dimensioned for the needs of enlarged storage

building, and thus, were clearly over-dimensioned for the needs of existing storage building. This feature led to problems with the temporary protective wall when a malfunction of supply air fans occurred.

The storage has two parallel supply air trains and analogously two parallel exhaust air trains. Normally, there is monthly change of train in service, but once the change of trains did not occur as expected. The running air supply fan stopped as expected, but the parallel one did not start. However, the change of trains at the exhaust air trains took place as expected. As the supply air ventilation was completely stopped, and the new exhaust air fans were too efficient, the situation caused an excessive underpressure inside the storage building.

At the same time preparations were made outside the end wall to begin the pulling down of the wall. An opening was made to the end wall and the temporary wall was exposed to the atmospheric pressure.

The excessive underpressure inside the storage building, caused by the malfunction of the supply air train, was estimated to be about 10 times greater than the design value of underpressure inside the storage building. This caused an inward bulging of the temporary protective wall, which was dimensioned to withstand an underpressure three times greater than the design value. The excessive underpressure caused a displacement of some elements of the temporary protective wall resulting in a loss of air tightness, although the major part of the temporary wall and supporting structures remained in their position. At this point the opening of the end wall was covered to restore the underpressure of the storage building. As a backup function the stopped fan had restarted to restore the supply air function.

The initiating event of the occurrence was later identified to be the control automation of the supply air train. The protection of the supply air fan tripped due to high temperature of the incoming water to the supply air heater. The set value for its maximum temperature was identified to be too low because the protection tripped due to a slightly higher than normal temperature.

4. The planned modifications for spent fuel storages due to the Fukushima accident

Due to the stress-tests for the nuclear power operators after the Fukushima accident, STUK required the operators to investigate how the nuclear power plants are prepared to and will survive with exceptional natural phenomena and disturbances in external power supply.

At Olkiluoto site the operator identified the following necessary modifications to improve the safety of spent fuel storage:

a connection to the storage building to feed cooling water from an external source,

spent fuel pool water level and temperature monitoring systems that are independent of power supply and that can withstand the design earthquakes,

improve storm water drainage,

prevent the seawater from flooding the storage building by plugging the space between the sea water pipe culvert and pipes,

transportable fire water pumps at the site, and

improved availability of raw water at the site.

Some of the modifications caused by these requirements were designed within the enlargement project, already before Fukushima accident. An example of this kind of modification is a cooling water connection

in the outside wall of the storage building. This connection allows feeding of cooling water to the fuel pool cooling system from a source outside the storage building.

At Loviisa site, the planned improvements due to stress tests are:

to analyse seismic resistance of fuel pools,

to add connections to feed cooling water from external sources,

to improve the route for steam to flow out via exhaust air conditioning, and

to improve the availability of water level and temperature monitoring.

5. Regulatory requirement modifications due to Fukushima

The stress tests revealed also some needs to modify the regulatory requirements. The new requirements will be implemented in YVL-guides during 2013. The requirements affecting the spent fuel storages are partly those the operators have already considered. The two main requirements are the concept of practically eliminated occurrences and the 72 h self-sufficiency criterion.

The concept of practically eliminated occurrences means that occurrences that may lead to early or vast radioactive release must be practically eliminated. For spent fuel storages this requirement means that the loss of cooling, which could lead to severe damages of spent fuel, must be practically eliminated.

For the spent fuel storages the 72 h self-sufficiency criterion means that in the event of loss of plant's AC power distribution systems there has to be resources at the site for at least 72 hours that enable fuel pool water level monitoring and cooling water availability.

6. Conclusions

This paper gives an overview of spent fuel management in Finland. The enlargement project of the spent fuel interim storage has emphasized the significance of detailed planning of modifications in this type of projects. Applying the new requirements to old structures is a challenging task. The lessons learned from Fukushima are taken seriously and the effects on regulatory requirements are carefully considered.

The Spent Fuel Management in Finland and Modifications of Spent Fuel Storages

Safety of Long Term Interim Storage Facilities
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Content of presentation

- Spent fuel management in Finland
- Enlargement project of a spent fuel interim storage
  - Operational occurrence
- Modifications in spent fuel storages due to Fukushima accident
- Modifications in regulatory requirements due to Fukushima accident

Nuclear power in Finland

Olkiluoto NPP (TVO)

- OL1&2 operating units - BWRs 880 MWe (-78, -80), SF storage
- OL3 under construction
- Decision in Principle for OL4
- SNF Repository site ONKALO

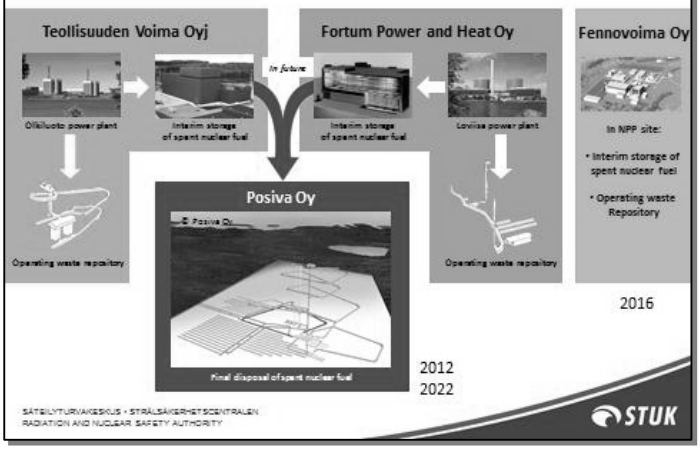
Hanhikivi NPP (Fennovoima)

- Decision in Principle for FH1, SF storage

Loviisa NPP (Fortum)

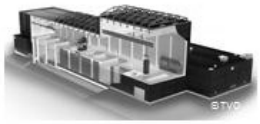
- LO1&2 operating units - VVERs 496 MWe (-77, -81) SF storage

Nuclear waste management and disposal in Finland



Enlargement project of spent fuel interim storage

- TVO spent fuel interim storage was commissioned 1988
- Spent fuel from OL1 and OL2, in future from OL3:
  - Extra capacity needed: 3 new pools

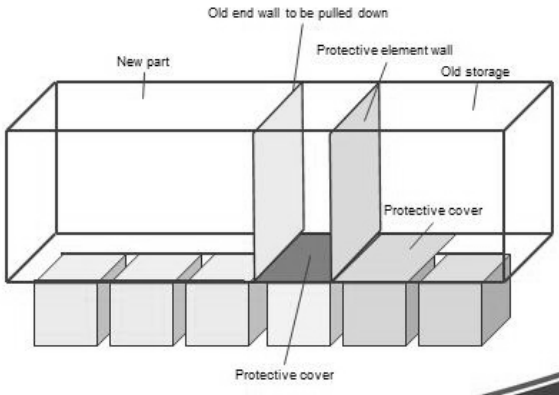


- Enlargement was conducted as a major plant modification: new safety requirements are applied:
  - To withstand the APC: cover slabs for the pools and landfill embankment outside the storage
    - The landfill embankment protects the pools from direct impact
    - The cover slabs protect the pools from falling debris
  - Dimensioning is an optimization task and acceptability is not always obvious

Safety of operating spent fuel storage during the enlarging constructions

- The construction activity at the vicinity of spent fuel pools
- Protection of an empty and filled spent fuel pools
  - Hollow-core slabs and light structures
- Before pulling down the end wall from between the new and the old part
  - Protective element wall was built to form a new border for radiation protection monitoring area

Protective structures of the old storage



Careful design of system modifications

- Operational occurrence:
  - Exhaust fans were changed at the early stage long before uniting the existing and the new part
  - Malfunction of supply air fans & a small opening to the end wall
    - Atm pressure to one side of the element wall, excessive under pressure to the other side

      → Inward bulging of the temporary wall

      → Loss of air tightness of the monitoring area

❖ The cause of the occurrence:

❖ Stopping of air supply due to temperature protection of the supply fan

Modifications to spent fuel storages due to Fukushima

Modifications to spent fuel storages due to Fukushima

STUK required the licensees to investigate how to

- survive with the exceptional natural phenomena
- disturbances in external power supply

Already planned before Fukushima

Results for spent fuel storages:

- External cooling water connection
- Water level & temperature monitoring independent from power supply
- At the site:
  - transportable fire water pumps
  - improved availability of raw water

Modifications to YVL guides due to Fukushima

- New requirements concerning the spent fuel storages
  - Practically eliminated occurrences
    - occurrences that may lead to early or vast radioactive release must be practically eliminated
    - SFP: the loss of cooling
  - 72 h self-sufficiency criterion
    - In case of loss of AC power supply there has to be resources at the site for at least 72 h that enable:
      - Fuel pool temperature and water level monitoring
      - Cooling water availability
- To be implemented in YVL guides during 2013

Conclusions

- Overview of the spent fuel management in Finland
- Examples to show the importance of detailed planning of the modifications at the site
- Applying new requirements to old facility can be a challenging task
- Lessons learned from Fukushima accident are taken seriously
  - Effects to regulatory requirements are carefully considered