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Options for the Interim Storage of Spent Fuel

Marjan Kromar
Institute "Jožef Stefan", University of Ljubljana,
Jamova 39, 61111 Ljubljana, Slovenia
E-mail: marjan.kromar@ijs.si

Bojan Kurinčič
Nuclear Power Plant Krško
Vrbina 12, 68270 Krško, Slovenia

Abstract – Different concepts for the interim storage of spent fuel arising from operation of a NPP are discussed. We considered at reactor as well as away from reactor storage options. Included are enhancements of existing storage capabilities and construction of a new wet or dry storage facility.

1 Introduction

Interim storage refers to the storage of spent fuel beginning with the discharge of spent fuel from a reactor and ending with its ultimate disposition, either by direct disposal or reprocessing. During the cooling time spent fuel is located in the spent fuel pool at a reactor site. However, the pool capacity is usually not sufficient to cover all fuel discharged during a NPP lifetime. If the final strategy is not available, intermediate storage facility has to be constructed before spent fuel storage issue become an obstacle for the plant operation.

All spent fuel from NPP Krško is stored in a spent fuel pool at the site. The pool contains stainless steel racks with a capacity of 828 fuel assemblies. Currently 442 locations are occupied with spent fuel. If we assume that the fuel will be discharged with a rate of 40 assemblies per year and 121 locations reserved for emergency core unload, capacities are sufficient for approximately 6 years of operation.

The choice of a particular storage option has to include consideration of different factors. Beside the general factors, such as safe operation and reliable storage, the following factors are usually considered:

- technical maturity
- operational consideration

- costs
- public perception

In this paper different available storage concepts are discussed. We considered at reactor (AR) as well as away from reactor (AFR) options:

1. AR storage enhancement - increase of the storage capacity within the existing spent fuel pool;
2. AR storage extension or stand alone storage - construction of a new storage facility interconnected to the original pool or standing alone but on the same site;
3. AFR storage - construction of a storage facility that is located away from the nuclear power station site.

2 Water pools

Water pools are the most widely-used, best-proven and mature spent fuel storage technique, since all nuclear power plants store the fuel in wet storage for variable periods after discharge from the reactor. About 90% of the spent fuel around the world is currently stored in pools. They are constituted by a reinforced concrete structure lined with stainless steel on the side that is in contact with the water. Spent fuel assemblies are stored in a storage racks mounted on a base of the pool. The racks provide spacing between fuel assemblies to prevent criticality and protect fuel from consequences of the earthquake.

Advantages:

- proven and mature storage method
- controlled fuel cladding condition
- good shielding
- visibility
- accountability and safeguards
- simple fuel handling.

Disadvantages:

- active nature of water cooling and purification systems
- waste processing

- maintenance requirements
- necessity of auxiliary support systems
- decommissioning
- high initial capital investments.

2.1 Reracking

Reracking is the most widely used technique as a first step to extend the spent fuel storage capacity of a nuclear power plant. Besides the technical reasons it is the most attractive economic solution. This method consists in redesigning the fuel storage racks in order to increase the number of spent fuel elements that can be stored in the pool. The main problems raised by the new design are the following:

- new structural analysis required for new loads
- capacity of the water cooling and purification system to remove excess heat produced by additional fuel elements
- maintenance of subcriticality
- shielding analysis due to additional fuel.

Advantages:

- increased storage capacity of existing pools, without necessity of creating new installations
- licensing process is simpler than for other spent fuel storage systems, since reracking is considered as extending the loading capacity of an already-existing pool
- low capital investment.

Disadvantages:

- additional capacities are not sufficient for the entire power plant lifetime
- additional fuel handling - risk of damaging the cladding
- decommissioning process is somewhat complicated.

2.2 Double tiering

The spent fuel pools are usually divided on three levels. The fuel storage racks are located in lower level. The intermediate level is used for fuel transfer and upper level serves for shielding the radiation caused by the fuel during transportation above the storage racks. The transfer level can be filled with additional tier of special cans loaded with a fuel assemblies, and thus used for the spent fuel storage. These upper tier cans are designed to rest on top of the lower tier racks and are connected at their upper end fitting to form the upper storage tier modules.

Advantages:

- increased storage capacity of existing pools, without necessity of creating new installations
- relative simple licensing process.

Disadvantages:

- the decommissioning process is somewhat complicated
- the last elements discharged after the final shutdown of a nuclear power plant will have to remain in the pool for several years, as required for proper cooling, which means some systems must remain operative
- shielding
- limited fuel availability
- accountability and safeguards.

2.3 Consolidation

This technique consists in the disassembly of spent fuel elements and of their reconfiguration in a canister designed for this purpose. The result of this process is the reduction of the stored volume, compared to the space initially occupied. Ideal ratio would be 2 to 1, thus duplicating the loading capacity of the pool (taking into account the fact that non fuel-bearing components (NFBCs) also have to be stored the actual ratio is lower).

Advantages:

- increase of at least 67% of capacity of existing pools (consolidation ratio of 2:1 for fuel and of 10:1 for NFBCs)
- licensing process is simpler than for dry storage systems.

Disadvantages:

- intensive handling of the fuel assembly - risk of damaging the cladding
- sophisticated operation and handling
- interference with plant operations
- waste generation
- accountability and safeguards
- prices.

3 Casks

3.1 Metal Casks

Metal casks are robust metal containers equipped with an internal fuel basket for holding the spent fuel elements. It is the most mature (in place since 1984 in USA) of all methods available for interim dry storage of LWR fuels. A further step in the development of metal casks has been the improvement of designs so that the same cask could serve for interim storage and for transport of spent fuel (dual purpose casks). Vendors offer a wide variety of designs e.g.:

- NAC-I28 S/T, NAC-STC
- TN-32, TN-40, TN-24
- Castor V/21, Castor X/33, Castor X/28
- MC-10

Advantages:

- highly modular designs - procurement can be adapted to the spent fuel discharges
- easy operation, maintenance and decommissioning
- simple control and installations
- spent nuclear fuel loading in the pool performed by using the same cask that will be stored
- spent fuel storage and transport carried out in the same cask - no need of further fuel handling for shipment after a storage period (dual-purpose casks)

- public perception.

Disadvantages:

- cladding temperatures higher than in other systems
- possibly long period required for licensing process
- prices.

3.2 Concrete storage casks

The concept is similar to the metal casks. The only difference is that the vessel of the cask is made of reinforced concrete lined with steel on the inside where an open or closed basket (canister) is placed. An example of a ventilated concrete storage cask is Sierra Nuclear VSC-24.

Advantages:

- materials easy to acquire
- quick and easy fabrication
- modular system
- lower prices than for metal casks.

Disadvantages:

- direct loading is not possible - necessity of loading an intermediate cask (transfer cask)
- handling operations are more complicated than for metal casks.

4 Concrete storage modules

This concept consists in the horizontal storage of stainless steel canisters in properly ventilated concrete modules (Nuhoms system). Two types of canisters for storage of PWR fuel have been developed so far by VECTRA: NUHOMS-7P, NUHOMS-24P.

Advantages:

- materials easy to acquire
- quick and easy fabrication
- modular system.

Disadvantages:

- complicated handling operations:
  - necessity of loading an intermediate cask
  - difficult alignment to introduce canister in storage module
- decommissioning process more complicated than for casks.

5 Vaults

The modular vault dry storage system uses sealed metal tubes arrayed and housed in a concrete structure to contain spent fuel. Inside the tubes the fuel is kept under nitrogen or other inert gas. Metal tube can contain single fuel assembly or canister of consolidated fuel or canister of fuel assemblies. System is modular and each module has up to 200 fuel assemblies. Cooling is provided by natural air ventilation system. The space required for modular vault storage systems is on the same order as that for spent fuel pools. Three designs are currently available:

- GEC-Alsthom Modular Vaults Dry System (Fort St Vrain)
- SGN CASCAD system
- SIEMENS/KWU FUELSTOR system.

Advantages:

- fuel cladding temperature is kept lower than in casks
- all equipment integrated in the same building
- fuel can be withdrawn if necessary without return to pool.

Disadvantages:

- use of safety related equipment
- requires more maintenance than casks and concrete modules
- long licensing period
- building and almost all equipment must be completely built from the beginning, although expansion is possible
- cask support is required for fuel loading and unloading
- decommissioning is complicated
- initial cost.

6 Conclusion

There are a number of safe and environmentally acceptable methods for storing spent nuclear fuel for periods of 50 to 100 years that are available. During the past years considerable experiences have been gained showing the mature status of technologies.

All options mentioned in the paper are licensable and can be developed to suit specific requirements. However, there is no "best" technology. In selecting a particular technology subjective and local issues as well as objective (technical and economic) need to be taken into account. Specific requirements can lead to different solutions from utility to utility.

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