Advantages on Dry Interim Storage for Spent Nuclear Fuel

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Abstract

When the nuclear fuel lose its ability to efficiently create energy it is removed from the core reactor and moved to a storage unit waiting for a final destination. Generally, the spent nuclear fuel (SNF) remains inside concrete basins with water within the reactors facility for the radioactive activity decay. Water cools the generated heat and shields radioactivity emissions. After some period of time in water basins the SNF can be sent to a definitive deposition in a geological repository and handled as radioactive waste or to reprocessing installations, or still wait for a future solution. Meanwhile, SNF remains stored for a period of time in dry or wet installations, depending on the method adopted by the nuclear power plant or other plans of the country. In many SNF wet storage sites the capacity can be fulfilled very quickly. If so, additional area or other alternative storage system should be given. There are many options to provide capacity increase in the wet storage area, but dry storages are worldwide preferred since it reduces corrosion concerns. In the wet storage the temperature and water purity should be constantly controlled whereas in the dry storage the SNF stands protected in specially designed canisters. Dry interim storages are practical and approved in many countries especially that have the “wait and see” philosophy (wait to see new technologies development). This paper shows the advantages of dry interim storages sites in comparison with the wet ones and the nowadays problems as terrorism.

1. INTRODUCTION

Every nuclear power plants use radioactive fuel to create energy. A nuclear reactor with 1GWe generates about 20,000 to 30,000 kg spent nuclear fuel (SNF) per year [1]. The management of this fuel is very important, especially nowadays because it is very difficult to get enough space on installations and the proposed alternatives cause controversies, as much politics as related to proliferation risks, hazards to environment and increase of fuel costs.

2. INTERIM STORAGE

There are two methods of spent fuel storage: wet storage in which water is the refrigeration medium and dry storage in which the refrigeration is made by air circulation. Figure 1 shows the interim storage concept.

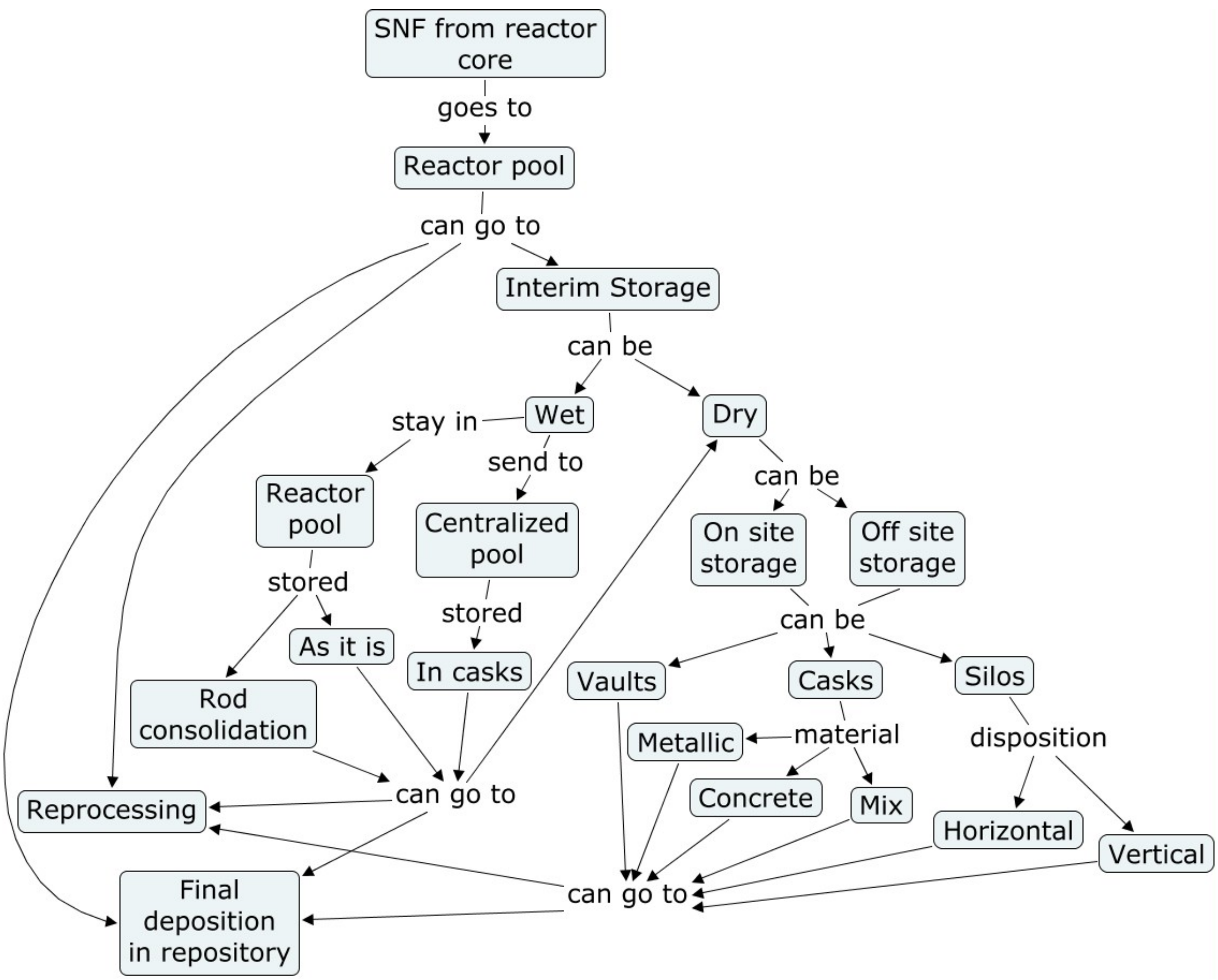

Figure 1- Interim storage concept

2.1 Wet Storage.

When the nuclear fuel is removed from the reactor core because it is not anymore efficient, (about 1/3 reactor fuel is spent and substituted every 12 to 18 months) [2], it is intensively radioactive or generally called “hot”. For the decay, SNF should be maintained certain time in water pools that exist in each commercial fuel installation. Water is an efficient shield and allows good refrigeration, but must be constantly purified. In the storage pool, radioactive decay and heat decrease with time. One ton of SNF from 600 MWe PWR (*Pressurized Water Reactor*) or BWR (*Boiling Water Reactor*) generates about 2,000 kW heat when recently removed from the reactor. This heat decreases to 10 kW after one year and to 1kW after ten 10 years in water pools storage [3]. The activity of the SNF also decreases with time.

To increase wet storage capacity one option is the replacement of the pool racks for another that allow the SNF compaction. By reducing the distance between the fuel elements results in a minimum of 30% net volume raising [4]. This option has been adopted in many countries [5]. Another possibility is the construction of additional pools or volume increase of the existing pools. One practice used in some countries is the transference of the SNF from to another place with more space as centralized pools that can store SNF elements from many reactors and are used in countries with small territorial dimensions.

SNF rod consolidation is another option to store more elements submerged in water. The SNF is disassembled and the rods are consolidated and again placed inside the pool. Storage capacity can be twice time higher (compaction rate 2:1, i.e. two SNF elements at the same place) [6].

2.2 Dry Storage.

Dry storage has been successfully adopted worldwide and differs from wet storage by the use of an inert gas or a slightly reactive gas inside the canister to avoid storage fuel oxidation. Metal or concrete as radiation barrier works as water in the wet storage. Heat cooling is made by the passive convection of environmental air instead water. Before be transferred to the dry storage, SNF must remain for some years in water pools for initial activity and heat decay.

Dry storage managing is less expensive since it provides all safety characteristics, doesn’t need electrical systems (necessary only in vault storage), periodic maintenance and a constant fuel monitoring, increasing the system reliability for longer periods. Another important characteristic is that the radiation shield is made by thick concrete, cast iron, steel, lead walls or a combination of them.

There are many types of dry storage installations as follows:

2.2.1 Vault storage

In this storage type, SNF is stored in a reinforced concrete building in which the exterior structures are radiological barriers and in their interior a great number of cavities on the floor are ready to receive the spent fuel elements. These cavities contain metallic cylinders in which externally air is insufflated or sometimes the air circulation is natural. This way the heat transfer between the cylinder and the environment allows SNF to be cooled by convection.

2.2.2 Silos storage

In this system, SNF is stored in metallic canisters, inside a concrete cylinder on the floor. The storage position can be vertical or horizontal. Concrete is the structural material and the radiation shielding (like the building in vault storage), as the canisters provide containment. Heat is removed by air convection through ducts in the concrete cylinders. Fuel transfer from reactor to silos is made through a special cask designed for this purpose.

2.2.3 Cask storage

Metallic casks

Usually, casks are thick wall cylinders (until 65 cm thickness) made of metal, concrete or a mixture of both. Metallic casks generally are made-up of cast steel with one or two lids that are bolted or welded in the cask body. The steel cask provides a leak-tight containment of the spent fuel and provides shielding against gamma radiation. The surface inside cask is lined with a special resin (in general polyethylene) that is the neutron absorber. There are winglets on the external surface for better heat transfer to the environment. The external surface of the cask has trunnions which allow the cask to be lifted and displaced. Shock absorbers of the cask installed at the bottom and the cover assure transport stability.

Concrete casks

Concrete casks have the same inner disposition that a metallic cask has. SNF are distributed in inner baskets inserted into these containers. Concrete is neutrons and gamma radiation shielding. Heat transfer is made through ducts located inside the cask that link the inner part to the external environment. Generally, concrete casks are heavier than the metallic ones since their wall thickness is greater and are less expensive than the metallic ones.

2.3 Advantages and Disadvantages of SNF Storage Systems

Wet storage installations have a worldwide high acceptance degree because the storage methods are standardized and well characterized. During the last 10-20 years, wet storage evidenced that the corrosion of fuel elements have been reduced [7], but with time the corrosion tends to increase because the fuel is submerged in water at temperatures about 40ºC and in this condition the oxidation in favorable, so this process should be well controlled. Other problems can occur during handling like SNF damage due to some kind of failure or through external events. The disadvantages of wet storage system are: redundancy for the electrical systems, cooling systems and the maintenance of water level between purposed limits to avoid environment and clad temperature increase when SNF is submerged.

All dry storages systems guarantee the shielding against radiation emitted from the radionuclides and cooling is passive. SNF can be removed from the reactor, dried and inserted into the cask and transported to the storage place. The same casks can be used for transport and storage. Storage can be at the same site of the reactor (on site storage) or not (off-site storage). If in the future the stored cask needs to be sent to another installation or to the reprocessing plant or even to a definitive repository, it can be easily transported without SNF elements transference. This way the casks have a great mobility.

Table I show some advantages and disadvantages according the storage type. [8].

Table I. Advantages and disadvantages on SNF storage installations.

Type	Advantages	Disadvantages
Wet Storage		
Pool	1. Inspection 2. SNF changing	1. Purity, cooling and H_2O level control 2. Corrosion
Racks modification	1. Inspection 2. SNF changing 3. More space provided in pools	1. Purity, cooling and H_2O level control 2. Corrosion
Rods consolidation	1. More space provided in pools.	1. Purity, cooling and H_2O level control 2. Corrosion
Centralized pools	1. SNF cylinders mobility	1. Purity, cooling and H_2O level control 2. SNF transportation
Dry Storage		
Vaults	1. No SNF corrosion	1. Lack of inspection 2. Forced cooling
Silos	1. No SNF corrosion 2. Passive cooling	1. Lack of inspection
Metallic casks	1. No SNF corrosion 2. Passive cooling 3. Transport cask is the same as storage 4. Casks mobility	1. Lack of inspection
Concrete casks	1. No SNF corrosion 2. Passive cooling 3. Transport cask is the same as storage 4. Casks mobility 5. Lower cost than metallic	1. Lack of inspection

Construction and maintenance costs of a dry storage are smaller than of the wet storage. For 5,000ton SNF in dry storage installation the cost is US$ 1,090,500 and for the wet storage installation the cost is US$ 2,440,000 (corrected to 2004) [9]. If one compares the cost of a metallic cask with that made of concrete it can be clearly seen that the concrete casks are less expensive and the manufacturing process is simpler. [10].

2.4 Terrorism in nuclear fuel storage installations

The terrorist attacks in Unites States on September 11, 2001 have triggered a multiplicity of activities in the area of physical protection of different types of nuclear plants in many countries. Although in Brazil this kind of attack has not been occurred such problem should be taken into account in future storage strategy and storage sites construction.

All kinds of nuclear fuel storages must have a reinforced concrete pad and all the physical security system demanded for these kinds of installations to minimize potential terrorist attacks.

A "robust" construction is necessary and this means that a facility for storing spent fuel is designed so as to be resistant to terrorist attacks as well. Such implementation is needed whether or not a repository is over or underground, or is wet or dry storage. After different terrorist attacks around the world, the new construction strategy should be implemented as a major element of a defense-in-depth for worldwide nuclear facilities.

To establish the ability of various dry-storage design approaches to put up various design-basis risks, full-scale experiments are needed. Specifications performance for dry storage must be developed with stakeholder input. The reinforcements must be seen as an important component of country security.

In case of terrorists attack, a SNF dry storage installation is safer than wet storage installation. Studies show that a passenger airplane at 800 km/h crashing against a SNF concrete cask will not damage this structure. [11]

3. CONCLUSIONS

After all these considerations it can be concluded that dry interim storage for spent nuclear fuel is more advantageous than wet storage. In dry storage the casks are more mobile and can be used both for storage and transport; however wet storage continues to be very helpful after SNF withdrawal from the core reactor before any other SNF interim storage.

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