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WHY IS A DRY STORAGE FOR SPENT NUCLEAR FUEL WASTE MORE APPROPRIATE?

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ABSTRACT

Nowadays high activity level nuclear waste has been gradually confined in dry shelters, differently than occurred in the previous years. This kind of storages is spreading everywhere. A well evident case is the storage for irradiated fuel elements in commercial nuclear reactors, also known as spent nuclear fuel (SNF). The interim storage, up to 20 years ago, was exclusively carried out through cooling water pools in which the spent fuel has been stored. Such kind of storage was used during the service life of the reactor and sometimes longer. If the nuclear installation had to be decommissioned another storage solution had to be found. At the present time, after a preliminary cooling of the SNF elements inside the water pool, the elements can be stored in dry installations. This kind of storage doesn't need complex radiation monitoring resulting in favourable construction and maintenance economy of both nuclear storage plants since the volume of the cooling water pools can be smaller. Among several types of existing dry storages, the convection vaults, concrete modules and double purpose casks can be evidenced. These casks can be used as multi-use devices for high activity level materials, i.e. can serve as an interim storage, used for transporting purposes and used as definitive packages for final deposition if so planned. This paper aims to present the advantages of a dry storage in comparison with the wet one (cooling water pools) for high activity level nuclear waste, including the SNF.

1. INTRODUCTION

High level waste (HLW) consists on irradiated nuclear fuel from nuclear reactors, also called spent nuclear fuel (SNF), as well those liquids produced during the reprocessing of SNF. The reprocessing of the SNF, results in a small volume of high activity radioactive liquid waste such as transuranic elements (Uranium-237, Plutonium-239, 240, 241 and 242, Americium, Neptunium) and fission products (Samarium, Xenon, Strontium, Iodine, Cesium). Part of this reprocessing waste, which is stored in special tanks, can be burned and immobilized in vitreous matrix. The resulting vitreous blocks classified as HLW are more easily transported in containers to the interim storage on-site.

The Brazilian Nuclear Program did not contemplate a storage system of high level wastes from nuclear power plants, neither spent nuclear fuels. Nowadays the spent nuclear fuel elements are stored in water pools in the nuclear reactors. The national politics for reprocessing intended for reuse of remained Plutonium or Uranium is still not defined.

This paper shows some worldwide solutions for the SNF that can be applied in interim storages for other type of HLW.

2. INTERIM STORAGE

Spent nuclear fuel can be safely shielded with water, or steel and concrete. Usually there are two types of spent fuel storage: wet storage in which water is the cooling medium and dry storage in which the spent fuel is kept cool by air circulation.

2.1. Wet Storage.

The spent nuclear fuel assemblies removed from reactor core (about 1/3 reactor fuel is spent and substituted every 12 to 18 months) [1] is intensively radioactive and usually called "hot". To allow the SNF decay it should be maintained for a time in water pools inside the building of commercial fuel plant site. These pools are designed with reinforced concrete walls, steel liners. Water is an efficient shield and allows good refrigeration, but must be constantly purified. In the storage pool, radiation decay and heat emitted from the assemblies decrease with time. One ton of SNF from 600 MWe PWR (Pressurized 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 [2].

2.2. Dry Storage.

Dry storage has been successfully adopted worldwide and differs from wet storage. Before be transferred to the dry storage, SNF must remain for some years in water pools for initial activity and heat decay. In dry storages the spent fuel is placed inside airtight stainless steel canisters. Fuel oxidation in these canisters is avoided by the use of an inert gas or a slightly reactive gas. Canisters are made of metal and/or concrete and are radiation barriers. Heat cooling is achieved by circulation around the outside of the metal canister by passive convection of environmental air vents on the side of the container.

The management of dry storage is less expensive since it provides all security and safety characteristics. Periodic maintenance and a constant fuel monitoring increase the system reliability for longer periods. Rigorous safety requirements allow a dry storage to withstand incidents, airplanes crash and weather conditions as floods or earthquakes. 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 type of storage, the SNF is stored in reinforced concrete buildings in which the exterior structures are the radiological barriers. The inner area has also metallic lined cavities on the floor that are ready to receive the SNF elements (Fig. 1). The pipes are externally refrigerated by insufflated air or sometimes by natural air circulation. The heat transfer between the pipes and the environment allows SNF to be cooled by convection.

2.2.2. Silos storage

In silos storage system, the SNF is inserted inside concrete cylinders lined with metallic canisters. These steel cylinders provide a leak-tight containment of the SNF. These silos stay above the floor surface (Fig. 2). The storage position can be vertical or horizontal. Concrete is the structural material and radiation shielding (like the building in vault storage). Heat is removed from the concrete cylinders by air convection through special ducts. Fuel transfer from reactor to this kind of silos is made through a special cask designed for this purpose.

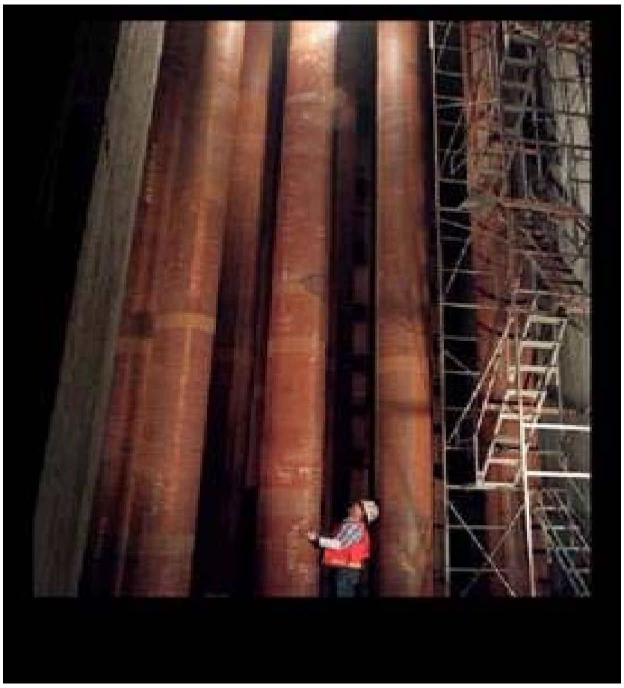

Figure 1. Metallic pipes view in a vault installation storage type for SNF. (www.qmetrics.com)

Figure 2. Argentine storage of SNF placed inside concrete silos (www.invap.net)

2.2.3. Cask storage

Usually the casks have a thick wall cylinders (~65 cm thickness) made from metal, concrete or a mixture of both. Metallic casks (Fig. 3) 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.

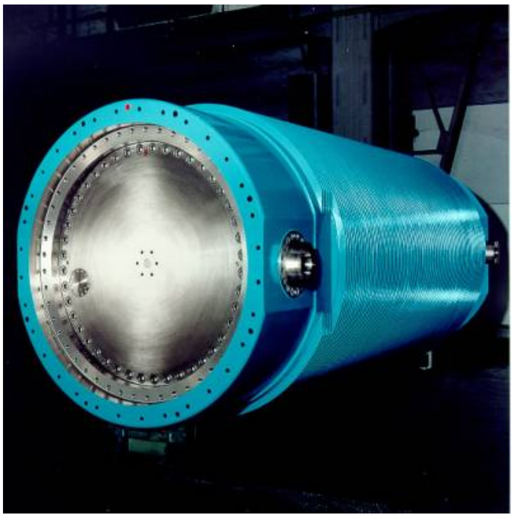

Figure 3. German metallic SNF cask – CASTOR (www.gns.de)

Concrete casks (Fig. 4) have the same inner disposition than the metallic cask. SNF are distributed in inner baskets inserted into metallic containers and then into the concrete cask. The concrete shields neutrons and gamma radiation. Heat transfer is performed through ducts located inside the concrete cask that link the inner part to the external environment. Generally, concrete casks are heavier than the metallic ones since their walls are thicker but are less expensive than the metallic ones.

Figure 4. Concrete casks at Palisades site, U.S.A. (www.bngfuelsolutions.com)

2.3. Advantages of SNF Storage Systems

Wet storage installations have a high worldwide acceptance because the storage methods are standardized and well characterized. During the last 10-20 years, wet storage evidenced that the corrosion of fuel elements has been reduced [3], however the corrosion tends to increase because the fuel is submerged in water at temperatures about 40ºC that favors oxidation, so this process should be well controlled. Other problem can occur during the handling, like the damage of SNF due to some kind of failure or external events. Disadvantages of wet storage system are: redundancy for the electrical systems, maintenance of the cooling systems and maintenance of the water level. It should be pointed out that a small loss of the integrity of a dry storage container is a correctable problem, while a loss of integrity of a wet storage pool could result in a fast loss of radioactively water, with more serious consequences, like increase of clad temperature.

All dry storages systems guarantee shielding against SNF radiation and a passive cooling. SNF can be removed from reactor, dried, inserted into the cask and transported to the storage place. The same casks can be used for transportation 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 casks need to be sent to another installation, to the reprocessing plant or even to a definitive repository, it can be easily transported without SNF elements retrieval to change type of casks. This way the casks have a great mobility. Advantages on SNF dry installation related to wet storage are shown in Table 1.

Table 1. Advantages on SNF dry installation related to wet storage.

Vaults	1. No SNF corrosion
Silos	1. No SNF corrosion 2. Passive cooling
Metallic casks	1. No SNF corrosion 2. Passive cooling 3. Transport cask is the same for the storage 4. Cask mobility
Concrete casks	1. No SNF corrosion 2. Passive cooling 3. Transport cask is the same for the storage 4. Cask mobility 5. Lower cost than metallic

Construction and maintenance costs of the dry storage are lower those of the wet storage. A 5,000ton SNF dry storage installation costs nearly US$ 1,090,500 and the wet storage installation for the same amount of SNF is about US$ 2,440,000 (corrected to 2004) [4].

Costs involving different types of casks have also a considerable difference. If one compares the cost of a metallic cask with one of concrete, it is clear that the last one is less expensive and the manufacturing process is simpler. [5].

2.4. Terrorism in Nuclear Fuel Storage Installations

The terrorist attacks upon the 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 sophisticated terrorists will not see them as attractive targets [6]. However, this vulnerability could be minimized by transferring SNF to underground sites as planned in the USA [6]. In Brazil, this kind of attack has not been occurred, but it must be taken into planning for a future storage strategy and the construction of storage sites.

All kinds of nuclear fuel storages must have a physical security system demanded for these kinds of installations to minimize potential terrorist attacks.

In the case of a terrorists attack, a SNF dry storage installation is safer than wet storage installation. One of the recommendations of Marsh and Stanford for the American SNF storage type is: “As much spent fuel as possible should be moved into the less vulnerable dry-storage type of cask” [6].

Studies show that an airplane at 800 km/h crashing against a SNF concrete cask will not damage its structure [7], but the impact against a building that contains a storage pool is different. The probable collapse of the building allied to the aircraft’s fuel tanks explosion and consequent burn would damage the entire SNF storing complex. The water could be spread out and/or mixed to the airplane fuel and evaporate because of the combustion heat. The damages occurred to the cladding would provoke the emission of fission products into the atmosphere together with the fire smoke, resulting in a catastrophic radioactive levels and a hard contamination of the atmosphere.

3. CONCLUSIONS

It can be concluded that a dry interim storage for spent nuclear fuel and high level waste is more advantageous.

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