DESIGN OF SPENT-FUEL CONCRETE PIT DRY STORAGE AND HANDLING SYSTEM

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SUMMARY

An advanced dry storage system design with highly improved storage efficiency of spent nuclear fuel has been developed. The new concept " Concrete Pit Dry Storage System" realizes a safe and economical solution to an increasing demand of storing spent fuel assemblies (SFAs) generated from commercial nuclear power reactors. The system is basically composed of a large mass concrete module which has densely arranged pit boreholes, sealed canisters containing spent fuel assemblies and a canister handling system.

The system is characterized by the following advantages compared with the existing concrete module type storage systems:

- higher storage efficiency can be achieved by the storage module filled with concrete which also gives a high shielding performance,
- simple handling technology is used for transfer and installation of the canisters at the storage facility as well as the transport cask of the canisters,
- surface contamination of the canister is prevented,
- lower radiation around the storage area is provided to reduce radiation exposure during handling and storage,
- high structural integrity of the facility is maintained by the concrete module with a simple construction,
- the ventilation gallery introducing cooling air to the pit borehole has an enough draft height to improve cooling performance of the system,
- a result of the design concept, the storage system can store higher burn-up SFAs with a short cooling period.

BASIS OF DESIGN

Figure 1 illustrates a schematic view of the proposed Concrete Pit Dry Storage System. The System is composed of four major components; the storage canister, the transport cask, the on-site transfer equipment, and the concrete storage module.

As noted in the previous summary section, a rather higher heat load per canister is allowed in each borehole due to the flexibility of the passive cooling system employed. The height of the borehole acts as a draft for natural convection. The height can be adjusted according to the heat load of the canister, thereby keeping the operability of canister placement in the borehole unchanged by using sufficient shielding thickness of the concrete. In addition, the maximum temperature of concrete can easily be kept under the allowable limit with this draft height. Therefore, the mechanical integrity of concrete is also maintained. Storage density of the system becomes larger with longer cooling time.

Major design parameters for the storage system are summarized in Table 1.

Table 1. Design parameters for the Concrete Pit Dry Storage System

Description		Design parameter
Fuel	Fuel assembly	PWR
	Initial enrichment	4.1 wt%
	Burn-up(max./av.)	48/44 GWd/MTU
	Burn-up multiplication factor	1.15
	Cooling time	5 years
	Heat load	16 kW/canister
Storage facility	Storage area	220 m^2
	Capacity	110 MTU
Criteria	Max. temperature for concrete	65 ℃
	Max. temperature for fuel rod	380 ℃
Transport cask	No. of accommodation	12 assy'/cask

SYSTEM DESCRIPTION

The Concrete Pit Dry Storage System is composed of four major components; the storage canister, the transport cask, the on-site transfer equipment, and the concrete storage module.

Storage Canisters

Each storage canister is designed as the so-called "multi-purpose canister" which will be used for transport and storage of SFAs with the same packaging. The canister is to comply with the IAEA transport regulations within its transport cask if the storage facility is located away from reactor. It has a cylindrical body made of stainless steel with a welded closure lid.

The cavity of the canister is fitted with a basket designed as a structural support of the fuel assemblies. In PWR case, it consists of stainless steel support structure and square tube shaped fuel cells fabricated from borated stainless steel to provide criticality control inside the basket assembly. The base material of the borated stainless steel is Type 304 and the boron content is 1 wt%.

Copper heat conductor plates are placed through the spaces between the fuel cells to provide radial heat transfer of the decay from SFAs. Using copper for the heat conductor plates, identified as a non-structural member, enables one to keep a larger volume inside the basket assembly to facilitate criticality control with the borated stainless steel. This type of structure can easily maintain its mechanical integrity and subcriticality under storage condition as well as during the normal and accident conditions of transport. An inert helium gas is back-filled in the canister cavity during transport and storage.

Transport Cask

The transport cask should also be designed to meet the IAEA transport regulations. This cask is used for carrying one sealed canister from a reactor site to the storage facility. The cask is cylindrical in shape with a multi-layer structure consisting of a stainless steel inner shell, an intermediate shell which is lead filled in the annulus between the two shells providing a gamma radiation shield, a carbon steel external envelope, and a layer of neutron shielding enclosed between the intermediate and the external envelope. A stainless steel lid closure system with elastomer O-rings provides the containment boundary of the transport cask. Top and bottom shock absorbers are attached to each end of the cask.

A layer of neutron shielding material is enclosed between the intermediate shell and the external envelope. Longitudinal copper fins bolted to the two shells through the neutron shield provide good heat transfer.

The surface of the canister will not be contaminated with pond water during fuel loading because an elastomer seal is installed between the top of the canister and the transport cask so that the pond water cannot intrude into the annulus interspace between the canister outer surface and the cask inside cavity.

On-site Transfer Equipment

The on-site transfer equipment is used for unloading the canister from the transport cask followed by consequent transferring the canister to the storage area and installing it into the pit borehole of the concrete storage module. In order to carry out these processes, a lifting crane with a handling tool to latch the canister is provided at the top end of the transfer equipment. This equipment also has the required features such as mechanical strength, shielding and heat dissipation from the canister during handling. Subcriticality and containment are basically maintained by the storage canister. The transfer equipment itself is lifted by a travelling crane to reduce the handling space of the storage area.

Concrete Storage Module

The canister storage facility is comprised of :

- the Concrete Storage Module with boreholes for storing the canisters
- the transport cask reception building
- the travelling crane
- the maintenance workshop and the administration building.

The boreholes for placing sealed canisters are densely arranged on a massive concrete module which provides efficient gamma and neutron shielding. Ventilation galleries (air inlet) are placed on the bottom of the concrete module to provide sufficient cooling air flow for natural convection which enhance heat dissipation from the canisters. The heated air goes up through each borehole and is directly release to the environment from the borehole lid which has air flow holes.

Additional shielding plugs installed both at the top and bottom of the canisters greatly reduce the neutron attenuation of the storage facility for safe and easy operation. The shielding plugs have a special shape not to interrupt cooling air flow for the canisters. This structure can optimize shielding and thermal performances of the storage facility which allow to accommodate higher burn-up SFAs with a short cooling time.

SAFETY FEATURES

Safety of this Concrete Pit Dry Storage System is primarily ensured by the following facility and equipment :

- Structural ;- The large mass of the reinforced concrete module and a top lid of the borehole also made of concrete provide sufficient integrity for seismic design and other hypothetical accident during storage.
- Shielding ;- The concrete module storage area, shielding plugs and the top lid efficiently reduce the radiation attenuation both for the operation/storage area and for the site boundary.
- Thermal ;- The ventilation galleries and a draft height provided by the pit borehole allows accommodation of higher heat load for the storage canister.
- Subcriticality ;- The basket structure employing borated stainless steel maintains subcriticality during transport and storage.
- Containment ;- The storage canister made of stainless steel with welded lid provides adequate confinement for the release of radioactive materials during storage.

For the Concrete Pit Dry Storage System, the design requirement to secure the shielding performance so as to prevent streaming of radiation through the channels of cooling air contradicts the requirement of reduced pressure drop in the pit borehole to supply sufficient cooling air. It would be the key technology for the concrete module type storage system to satisfy these requirement simultaneously from a safety and economical viewpoint.

SYSTEM OPERATION

Fuel loading and preparation for transport of the storage canister is carried out at the spent fuel pond. As previously noted, the surface of the canister body will not be contaminated with pond water and this could prevent possible activity release to the environment during storage. After welding the canister lid and drying the cavity, the cask lid is screwed to the cask body and then the cask is transported to the storage facility. The canister is lifted up into the transfer equipment at the cask reception building and is placed on the canister support structure installed at the bottom of the borehole of storage module. The bottom shielding plug should be positioned prior to the canister placement. The top shielding plug and the borehole lid are installed after the canister placement. When the canister loading into a borehole is carried out, any additional shielding would not be required for loading operation because the individual borehole, surrounded by concrete, provides sufficient shielding performance.

CONCLUSION

The Concrete Pit Dry Storage System allows the storage of higher burn-up SFAs, which have a larger heat output and activities, with a reduced storage area and a simple construction using a concrete module. This system will provide an advantage in terms of safety and economic both for an on-site storage package and a large capacity storage facility.

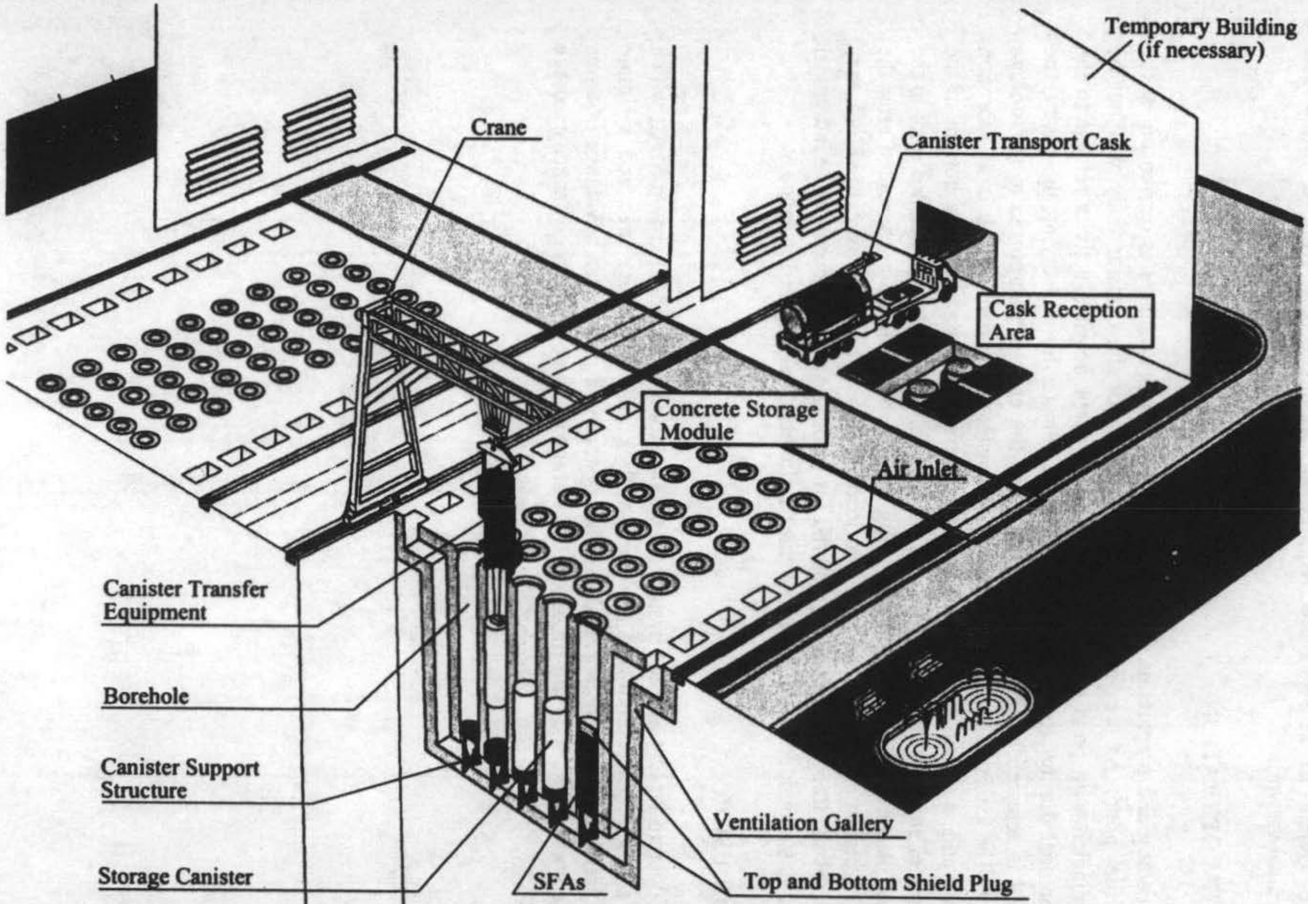

Figure 1 Concrete Pit Dry Storage System