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A study of the probabilistic risk assessment to the dry storage system of spent nuclear fuel

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ABSTRACT

Due to the large power supply in the energy market since 1960s, the nuclear power planets have been consistently constructed throughout the world in order to maintain and supply sufficient fundamental power generation. Up to now, most of the planets have been operated to a point where the spent fuel pool has reached its design capacity volume. To prevent the plant from shutdown due to the spent fuel pool exceeding the design capacity, the dry cask storage can provides a solution for both the spent fuel pool capacity and the mid-term storage method for the spent fuel bundles at nuclear power planet.

Currently, the dry cask storage system and relevant operating procedures have also gradually been deployed and consistently developed in order to facilitate the dry storage for the spent fuel bundles. In other words, spent fuel bundles dry storage and its safety has become an important issue and will directly affect the smooth operation of the plants once the spent fuel pool reaches its design capacity. Plants in the United States, Nuclear Regulatory Commission, the Office of Nuclear Material Safety and Safeguards (NMSS), the Office of Nuclear Regulatory Research (RES) and Spent Fuel Project Office (NMSS) have jointly developed a pilot methodology for probabilistic risk assessments. Adopting quantitative and qualitative evaluating methods to the subject BWR plants based on the handling, transfer and storage three phases. Obtaining the annual risk for one cask in terms of the individual probability of a prompt fatality within 1.6 km and a latent cancer fatality within 16 km can provide useful risk information for the subject BWR plant.

This pilot study used NUREG-1864 [1],"A Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Planet", related generic data and built prototype models for risk assessments in Taiwan Nuclear Power Plants. This pilot study investigated the handling, transfer and storage three phases to establish its risk evaluating methodologies, which includes initialing events, failure probabilities for canister and cask under mechanical loads and proceeded risk assessment for all three phases using quantitative fault tree analysis. The results of this study can be as a reference for future more detailed developments of the dry cask storage system risk assessments at Taiwan Nuclear Power Plants.

1. Introduction

To prevent the spent fuel bundles from exceeding the capacity of the Spent Fuel Pool and consequently causing the units to shutdown operation, dry cask storage provides an up-to-date solution for the nuclear spent fuel bundles storage. Dry cask storage system also plays an important role for the current spent fuel bundles mid-term storage before the long-term storage methods of the spent fuel bundles can be commercialized and implemented.

With the rapid developments of the dry cask storage systems and operating procedures, maintaining safety operation and public safety are crucial issues at both Licensees and Regulatory managements. In order to achieve the safety goal of the dry cask storage system, risk assessments relevant methodologies can be applied and adopted into the safety evaluation for the dry cask storage systems or operating procedures where the potential operating risks can be identified and safely operating procedures can be enhanced.

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Nomenclature

BWR	Boiling Water Reactor
FSAR	Final Safety Analysis Report
IE	Initiating Event
ISFSI	Onsite Independent Spent Fuel Storage Installation
NPP	Nuclear Power Plant
NUREG	Nuclear Regulatory Commission Regulation
PRA	Probabilistic Risk Assessment
SBGT	Standby Gas Treatment System
SSC	Structure, System, Component

Overall the dry cask storage system consists of three processing phases, namely handling, transfer and storage.

(1) Handling phase: Spent fuel bundles lift off the racking system in the spent fuel pool and load into the canister. The canister is then lifted out of the spent fuel pool onto the preparation dock for the processes of draining, drying, inerting and sealing. Move the transfer cask at very low height above the fuel handling floor to the equipment hatch preparing for lowering to the

Table 1
34 processing stages of the dry cask storage system.

Stages	Taiwan BWR NPP cask expected dropping height (M)	NUREG-1864 cask expected dropping height (M)
Handling phase		
1. Loading fuel assemblies into the MPC	5.07	4.8
2. Placing the MPC lid onto the MPC and engaging the lift yoke on the transfer cask	0	0
3. Lifting the transfer cask out of the cask pit	12.51	13
4. Moving the transfer cask over a railing of the spent fuel pool	1.0	0.9
5. Moving the transfer cask to the preparation area (1st segment)	0.3	0.3
6. Moving the transfer cask to the preparation area (2nd segment)	0.3	0.3
7. Moving the transfer cask to the preparation area (3rd segment)	0.3	0.3
8. Lowering the transfer cask onto the preparation area	0.3	0.3
9. Preparing (draining, drying, inerting, and sealing) the MPC for storage	0	0
10. Installing the short stays and attaching the lift yoke	0	0
11. Lifting the transfer cask	0.3	0.6
12. Moving the transfer cask to exchange bottom lids of the transfer cask (1st segment)	0.3	0.6
13. Moving the transfer cask to exchange bottom lids of the transfer cask (2nd segment)	0.3	0.6
14. Replacing the pool lid with the transfer lid	0.1	0.1
15. Moving the transfer cask near the equipment hatch	0.3	0.6
16. Holding the transfer cask	0.3	0.6
17. Moving the transfer cask to the equipment hatch	0.3	0.6
18. Lowering the transfer cask to the overpack through the equipment hatch	29.3	24.4
19. Preparing (remove short stays, disengage lift yoke, attach long stays) to lower the MPC	0	0
20. Lifting the MPC and opening doors of transfer lid	6.0	5.8
21. Lowering the MPC through the transfer cask into the storage cask	6.0	5.8
22. Moving the storage cask into the airlock on rollers	0	0
Transfer phase		
23. Moving the storage cask out of the airlock on rollers	0	0
24. Moving the storage cask away from the secondary containment on rollers	0	0
25. Preparing (installing lid, vent shield cross-plates, vent screens) the storage cask for storage	0	0
26. Lifting the storage cask above the rollers with the overpack transporter	0.1	0.1
27. Moving the storage cask above a cushion on the preparation area	<0.1	<0.1
28. Holding the storage cask above the cushion while attaching a Kevlar belt	<0.1	<0.1
29. Moving the storage cask above the concrete surface of the preparation area	0.3	0.3
30. Moving the storage cask above the asphalt road	0.3	0.3
31. Moving the storage cask above the gravel surface around the storage pads	0.3	0.3
32. Moving the storage cask above the concrete storage pad	0.3	0.3
33. Lowering the storage cask onto the storage pad	0.3	0.3
Storage phase		
34. Storing the storage cask on the storage pad for 20 years	0	0

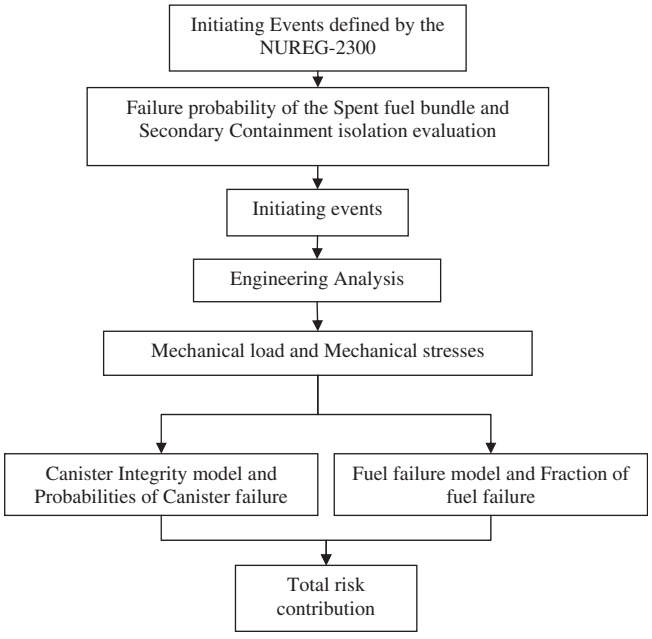

Fig. 1. 34 processing stages of the dry cask storage system.