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# Nonlinear dynamic impact analysis for installing a dry storage canister into a vertical concrete cask

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ABSTRACT

In this paper, a series of dynamic impact analysis for installing a dry storage canister into a vertical concrete cask (VCC) is performed. The dry storage system considered herein is called HCDSS-69, recently developed by INER and being capable of accommodating 69 bundles of BWR spent nuclear fuels. The impact accident is stemming from a conservative consideration of accidental movement when the canister is being hoisted into a VCC. According to NUREG-0554, the accidental movement is conservatively simulated by 80 mm- and 160 mm-height free-drop motions and then with straight and 2°-oblique impact to a pedestal in VCC. A symmetric fully 3-D finite element model is built and analyzed using the explicit finite element code, LS-DYNA. Geometrical, contact, and material nonlinearities are all taken into account. The analysis result concludes that the permanent deformations of the canister are not severe to affect fuel retrieve after the impact accident and the maximum stress intensity in the canister shell can meet the ASME code appendix F F-1340, preventing the leakage of radioactive materials. The study also found that with properly reducing the wall thickness of the pedestal cylinder, the maximum acceleration and permanent deformation of the canister can be much alleviated, even though the drop height is increased to the double of the required brake distance specified in NUREG-0554. The damages of the pedestal in each analysis are moderate so that the heat transfer condition after the impact accident can be bounded by the off-normal event for half-blockage of air inlets.



## 1. Introduction

With the aggravation of global warming and climate change, the living with low-carbon emission and energy saving is being advocated worldwide. Having a characteristic in low-carbon emission, the nuclear energy continues to be a good option for power resource in the future. However, the handling of highly radioactive spent nuclear fuels and the safety operation during the complex and huge natural disasters like those happened in Japan 2011 strongly impacts the public confidence on the use of nuclear energy. Fortunately, the Fukushima event also proved that the dry storage system is able to successfully withstand the huge natural disasters.

Spent nuclear fuels discharged from reactor core are commonly stored in spent fuel pool (SFP), not only for shielding radiation by the water in SFP but also for removing residual heat through coolant circulation. Such kind of so-called wet-storage is the way adopted by most current in-service nuclear power plants (NPP). However, most of NPPs built in 70 s and 80 s with licenses to be renewed do not have enough capacity for spent fuel storage, even though their SFP has been replaced by high-density fuel racks. The independent spent fuel storage installation (ISFSI) is thus adopted as an interim storage method before final disposal policy is determined.

In US, many dry storage systems have been successfully developed and applied to practical nuclear engineering practice, such as the HI-STORM and UMS systems respectively developed by Holtec [1] and NAC [2]. Recently, the institute of nuclear energy research (INER) in Taiwan also deployed a project to develop an experimental dry storage system called HCDSS-69. It is designed in accordance with the needs of the NPPs in Taiwan and being capable of accommodating 69 bundles of BWR spent nuclear fuels. The system design and analyses are in accordance with 10 CFR72 [3], ANSI/ANS 57.9 [4], the applicable sections of the ASME Code [5], and the ACI code [6]. The design of HCDSS-69 system also follows guidance of the standard review plans (SRPs), NUREG-1536 [7] and NUREG-1567 [8] published by US NRC. The aim of SRPs is to

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standardize the review processes to the license application of dry storage facilities. The SRPs clearly instruct that off-normal and accident conditions must be addressed in the safety report of ISFSI applicants. The off-normal event commonly considers the off-normal ambient temperature, off-normal handling, half-blockage of air inlet, and so on. The occurrence frequency of the events is around once per year. The accident event considers more sever accidents which may occurs only one time for entire service life of ISFSI, such as the extremely natural disasters and handling drop impact accidents. Obviously the scenarios of events should be made up in accordance with the ISFSI operational procedures. The assessment on handling impact accident of dry storage cask should be provided in the safety analysis report.

In order to provide applicants for an NRC license under 10 CFR Part 72 with a method for evaluating storage casks for low velocity impact conditions, the NRC has conducted a series of drop test studies of a solid steel billet and a near-full-scale empty cask in the Sandia National Lab. (SNL) and Lawrence Livermore National Lab. (LLNL), respectively. The experimental results reported in NUREG-6608 [9] are compared and verified by those of numerical simulation using the explicit finite element code DYNA3D [10] developed in LLNL. Since then employment of explicit finite element code for waste cask drop impact simulation has become intensive. Many researchers and engineers thus employed the explicit finite element code to conduct their drop impact analyses. Huang and Wu [11] studied a VCC tip-over impact using a simplified canister model

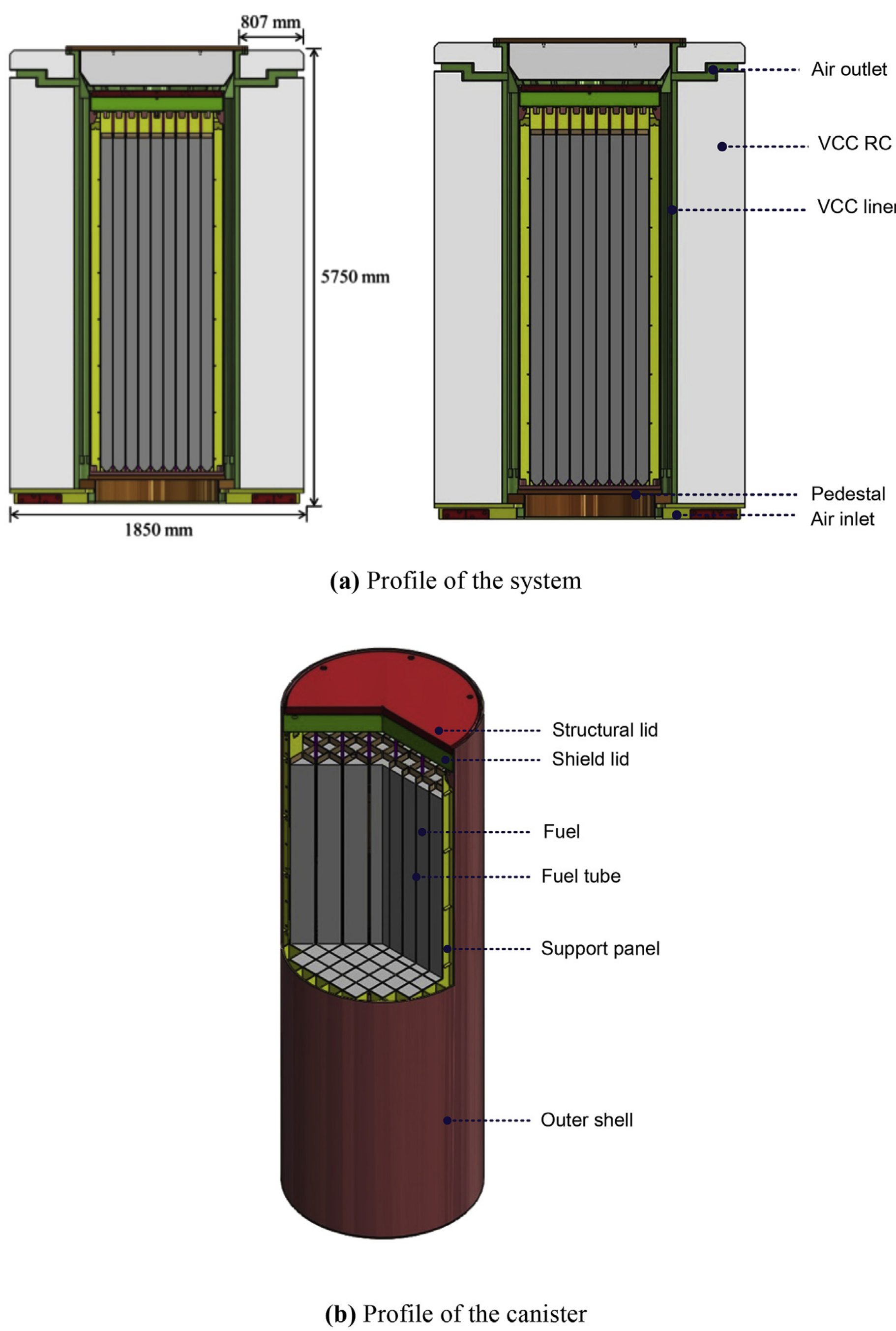


**Fig. 1.** Schematics of HCDSS-69.