International status of the dual purpose cask designed for both transport and storage of spent fuel

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Abstract. With the development of nuclear power reactors, the volume of spent fuel discharged from reactors which needs to be stored is growing. As the result of delays in decisions on spent fuel disposition, the volume of spent fuel discharged from reactors in an increasing number of cases, exceeding the spent fuel pool capacities in China. Additional storage capacity is needed. Options for additional storage include wet storage in some form of storage pool or dry storage in a facility or storage casks built for this purpose. One of these options is the use of the dual purpose cask designed for both transport and storage. These dual purpose casks are an attractive option because of their flexibility and economy efficiency. However, there are some issues need to be discussed and there are separate regulations that need to be complied with for both transport and storage for the dual purpose cask. This paper reviews the international status of the dual purpose cask designed for both transport and storage of spent fuel. Some dual-purpose cask safety related issues, such as supervision, dual-purpose cask safety design features, dual-purpose cask safety research and testing, are reviewed. These experiences from international different nuclear power plants can provides a reference for the development of dual-purpose casks in China.

1. Introduction

With the development of economy, the demand for energy is increasing. The nuclear energy as a clean energy found general acceptance. Since the first nuclear power plant was connected to the power grid, the nuclear energy has been increasing. According to the long term planning of nuclear power in china, the total installation capacity of nuclear power plants will be up to 58,000,000 kw [1-3]. Meantime, with the development of nuclear power, the storage capacity of spent fuel pool is not enough, spent fuels are badly in need of transportation and storage. At present, the capacity of spent fuel treatment and disposal facilities is limited in China. The total amount of spent fuel in nuclear power plants is increasing, and may exceed the storage capacity of spent fuel pools in the future. Therefore, there is an urgent need to promote the development of China's spent fuel treatment and storage facilities. At present, the spent fuel dual-purpose cask used for storage and transportation has been greatly developed after decades of actual operation. Different nuclear power plants have used dual-purpose casks for temporary storage of spent fuel in the United States, France, Germany, Japan, Russia and so on [4-8].

The dual-purpose cask has two functions of transportation and storage, which is an effective means for the final storage and disposal of spent fuel. However, just because the dual-purpose cask has both transport and storage functions, it must meet simultaneously both regulations requirements of transportation and storage. So the cask design should consider safe transportation, safe storage, and safe post-storage transportation. At present, the special legal guidance for dual-purpose casks is still
not perfect, and the dual-purpose cask safety design and safety analysis methods also need to be further improved in the World. Internationally, seminars were held specifically for the safe operation of spent fuel dual-purpose casks. Consensus was formed through experience exchange and group discussions, and special guidance documents were issued to guide the safety of dual-purpose cask transportation and storage [9]. This paper analyzes the international status of dual-purpose cask and related issues that should be considered for the safety design and safety verification of the dual-purpose cask as a temporary storage measure. Some help is expected for the development of dual-purpose casks in China.

2. The development status of dual-purpose casks

At present, some nuclear power plants in different countries have used dual-purpose casks for temporary storage of spent fuel, and have accumulated a lot of experiences of design, verification, approval, monitoring and inspection of dual-purpose casks, such as the United States, France, Germany, Japan, Russia and so on. In order to provide guidance for IAEA member states to develop dual-purpose casks for spent fuel transportation and storage, one dedicated system analysis group has set up for the safety of spent fuel transportation and storage dual-purpose casks.

2.1. Supervision

The IAEA spent fuel management agencies include Department of Nuclear Energy, Department of Nuclear safety and security (Division of Radiation, Transport and Waste Safety) and Department of safeguards (Division of Nuclear Fuel Cycle and Waste Technology). Radioactive waste management regulations include General Safety Requirements (GSR) Part 4 (Safety Assessment for Facilities and Activities), GSR Part 5 (Predisposal Management of Radioactive Waste), Specific Safety Requirements (SSR)-5 (Disposal of Radioactive Waste), General Safety Guide (GSG)-3 (The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste), Specific Safety Guide (SSG)-23 (The Safety Case and Safety Assessment for the disposal of radioactive waste), and SSG-15 (Storage of Spent Nuclear Fuel). An international working group has held several technical meetings since 2011, resulting in multiple outcome documents such as Package Design Safety Reports for the Transport of Radioactive Material (2012, P64) and Preparation of a Safety Case for a Dual Purpose Casks For Storage and Transport of Spent Nuclear Fuel (2013, P141), solving the IAEA related standards does not fully guide the practice of spent fuel dual-purpose casks [9].

The United States is currently working on a dual-purpose cask to discuss issues related to the regulatory standards for dual-purpose casks, mainly to introduce new regulations or to make changes. Currently, the US Nuclear Regulatory Commission (NRC) revised 10 CFR Part 72 and 10 CFR Part 71 and approved the Dry Storage System (DCSS) license extension to 40 years. At the same time, the NRC is evaluating the transportation of high burnup fuels that has been in storage in a configuration that challenges inspection capabilities. In addition, the United States is currently working on the issues that subsequent storage of high burnup fuel after transport from a previous storage site [10].

Germany currently has a lot of experiences in the management of dual-purpose cask licenses [11]. In the case of conventional operation in the manufacture, loading and transportation of dual-purpose casks, the package design license period is 5 years. If the dual-purpose cask is used for storage, the package design license period is 10 years and an evaluation report should be submitted to clarify these changes in regulations and design method. Additional implementation experience feedback is required and the aging management should be assessed when the loaded cask is removed from the storage facility. Currently, 9 storage permit procedures are required when the temporary storage period for high-level waste is 40 years. The manufacturing and testing procedures for all Class I and Class II components of the dual-purpose cask shall be in accordance with the “Fabrication and Test Plans”. Each supplier should have a quality assurance system which need undergo a GNS（Gesellschaft für Nuklear-Service mbH）(design) and BAM（Federal Institute for Materials Research and Testing）approval review. In addition, there are approximately 700 test steps for each cask and additional
check items performed by GNS and related field experts are required. At the same time, approximately 20 documents and approximately 1700 pages of documentation per cask need to be prepared.

There are currently 14,000 spent fuels need to be stored and 1062 spent fuel components are stored in dual-purpose casks and a lot of experiences in the safety regulation of dual-purpose casks have be accumulated in Spain [12]. Dual-purpose casks are required to meet transportation and storage requirements. At the same time, storage cask design guidelines and transportation cask design guidelines must be considered during transportation and storage, and must be independent and consistent with regulatory requirements of IS-20 (Safety Instructions: IS-20 (storage Cask)). At present, the dual-purpose cask storage license period is 20 years and the transportation license period is 5 years. The transportation permit must meet the relevant regulatory requirements of IS20 (with regard to storage cask), IS29 (Safety Instructions: IS-29 (storage facility)) and corresponding evaluation and inspection control were performed by CSN (CONSEJO DE SEGURIDAD NUCLEAR). Simultaneously manufacturing control must be checked by a third party and the compliance with the requirements of transportation and storage should be reviewed before the spent fuel loading. During the period of service, the cask inspection records should be able to explain its suitability for transportation regulations, including the cask manufacturing certification documents and usage history. The operational experience is notified to the regulatory department and the safety evaluation is conducted annually. The approval of transportation license requires the results analysis of the cycle inspection before transportation and determines the interface between the responsible entities. With regard to design modifications, it is necessary to state that the safety performance meets the relevant regulatory requirements IS20 (with regard to storage cask) and IS35 (Safety Instruction: IS-35 (Design Modifications)). The license extension or renewal should be justified and the system security related components are not affected during storage period.

AREVA TN is currently the world's more experienced dual-purpose cask technology exporter and more than 300 TN®24 casks are in service in the United States, Japan, Belgium, Sweden, Armenia, etc. Base on surveillance requirements every 6 months an external visual inspection of the outside surface of cask should be operated. Base on the leak monitoring requirements the interspace between the lids (or gaskets) which is filled with pressurised helium should be monitored and the leak system is connected to the 3 pressure sensors in order to permanently control the pressure in the lid interspace (or gasket inter lids). Base on radiation monitoring requirements no continuous radiation monitoring required during storage and radiation monitoring is based on utility requirements at storage building. At present, dual-purpose cask usually has a transportation permit for 5 years in France and the transportation permit will be extent every 5 years if the current regulations are met [13,14].

Belgium has a lot of experiences in dry storage of spent fuel dual-purpose casks. Belgian spent fuel is stored in spent fuel pools and is also stored in dry dual-purpose casks. At present, it has not yet been decided whether the spent fuel in storage will eventually be post-treated after transportation or directly storage after transportation. With regard to the validity of the package design approval during loading, the regulations require dual-purpose casks to maintain on-site transportability during storage[15].

2.2. Dual-purpose cask safety design features
The dual-purpose cask generally adopts a double-lid barrier system with metal and elastomeric seals and a leak monitoring device or a pressure monitoring device at a relevant part of the cask which keep continuous leakage rate monitoring during storage. The following sections show design features of some kinds of dual-purpose cask.

In the United States, different kind of dual-purpose casks are in using, such as HI-STAR 100, TN-40, TN-68 [5,6]. HI-STAR 100 adopts the concrete as the wall of the vessel to provide neutron and gamma shielding (see Figure 1).

CASTOR series of cask and MOSAIK series of cask were developed by GNS in Germany, which can be used for transportation and storage of high-level waste and spent fuel [11]. The large volume ductile iron cask adopts two-layer sealing with metal gasket and is comprised of internal neutron moderation unit, cooling fines, pressure monitoring equipment, etc. (see Figure 2). The CASTOR®
dual purpose Cask has a special protective cover during storage and the impact limiters are installed during transportation.

In Spain, there are currently 1062 spent fuel components stored in dual-purpose casks. The dual-purpose cask adopts lead as the gamma shielding material and the boron-containing resin as the neutron-moderator material [16]. The impact limiters are installed at both ends of the cask during transport (Figure 3).

The French dual-purpose cask adopts a double-layered sealing structure with a metal gasket [13,14]. The cask is forged from steel and provides gamma shielding function. The external neutron shielding resin is surrounded by a stainless steel shell. The continuous leak rate monitoring system is used to prove the containment barrier. The boron-containing aluminum alloy and stainless steel are used to ensure the criticality safety. Figure 4 is the structural chart of the TN®24 cask.

**Figure 1.** HI-STAR 100 dual-purpose cask structure chart.

**Figure 2.** CASTOR® Cask dual-purpose cask structure chart.

**Figure 3.** Structure of the ENUN 32P dual-purpose cask structure chart.

**Figure 4.** Structure of the TN®24 dual-purpose structure cask.
Japan has decades of dual-purpose cask design and manufacturing history, and developed several types of dual-purpose casks [8,9,17]. The cask structure characteristics includes the two-layer seal a metal pad is adopted, and the cavity is set negative pressure, and positive pressure is set between the two seal boundary, and the structural materials and resin/propylene glycol provide the gamma and neutrons shielding function, and boron-doped stainless steel and aluminum alloy are used to ensure critical safety, and heat sinks are adopted.

2.3. Dual-purpose cask safety research and testing
The safety performance evaluation of dual-purpose casks is mainly for four safety aspects of containment of radioactive materials, shielding, critical safety, and heat dissipation. Due to the need to meet both transportation and storage requirements, there are many safety performance evaluation test items that need to be carried out. Some factors should be considered such as basic safety requirements (inclusion, shielding, critical, thermal etc.), radiation monitoring, and aging of cask metal materials. In addition, natural factors, such as earthquakes should be also considered. When storage buildings collapsed the basic safety functions should be unaffected, and the shielding and heat dissipation functions should be restored, after reasonable measures and certain time should be taken. Multiple incidents should be considered at the same time. In the case of artificial external events, safety must be guaranteed [18-20].

At present, the international dual-purpose cask generally adopts a double-layer sealing structure with the metal sealing pad, and a leakage monitoring device or a pressure monitoring device is installed at a relevant part of the cask to ensure continuous leakage rate monitoring during storage of the dual-purpose cask. In this context, for instance, a research program was done to study the cask sealing performance by the annual temperature tolerance test at room temperature [21]. Figure 5 is a photograph of two types of cask lids and the leak rate versus time curve and the degradation/aging data of the gasket was obtained by testing. In the Type-I model, the cask body and lid are made of forged carbon steel, the sealing surface is overlaid with stainless steel welding, and a double metal gasket is installed. In the Type-II model, the cask body is made of ductile cast iron, an inner metal gasket and an outer rubber gasket were installed.

It is very important to study the influence of vibration on the containment performance of the metal gasket during the transportation of the dual-purpose cask, especially for the case of storage after transportation. A related research program focuses on two aspects. First is the effect of vibration on the sealing performance of the aged gasket. Second is the sealing performance after the long-term in-using of the gasket [22]. The results show that when the radial amplitude of the cask cover exceeds 0.02 mm and the maximum radial displacement is 0.1 to 3 mm, the sealing performance cannot be restored. Figure 6 is a plot of cask leakage rate as a function of radial amplitude.

![Figure 5. Structure of two cask lids.](image1)

![Figure 6. Cask leakage rate as a function of radial amplitude.](image2)
When the spent fuel dual-purpose cask is used to store spent fuel, it is stored in a storage facility centrally, and relevant research should be conducted on the heat dissipation performance of the storage facility. In addition, during the transportation and storage of the dual-purpose cask, corresponding auxiliary facilities are required whose reliability should be tested. At the same time, attention should also be paid to the retrievability of spent fuel from the dual-purpose cask after long-term storage.

3. Dual-purpose cask safety related issues
At present, there is no unified management system for the safety design, safety evaluation, licensing, monitoring and inspection of dual-purpose casks. Relevant issues that need to be urgently addressed. For example, regulatory requirements change how to influence the design approval and storage permit for transportation casks and how to ensure the safety of transportation after long-term storage of dual-purpose casks. When the packages do not meet regulatory requirements after long-term storage, if repackaging or secondary packaging is required or special arrangements are made in accordance with IAEA SSR-6. When the cask design does not meet the requirements of the user’s regulations the competent authorities how cooperate. How to assessment the uncertainty of the performance aging test. How should a sufficient safety margin be set [23,24].

When the requirements of transportation and the requirements of storage are contradictory, how dual-purpose cask design should be worked out. The aging management project whether should be included in the design scope. The fuel design party whether should consider the later spent fuel transportation and storage problem when designing the fuel. The dual-purpose cask whether should be designed to consider aging uncertainty and to deal with future deferred storage.

Other related issues that should be addressed in the safety performance study of spent fuel dual-purpose casks. For example, how the deformation of cask-related components effects of the spent fuel recovery.

4. Conclusions
The dual-purpose cask has both transport and storage functions and is an effective means for the storage and disposal of spent fuel. This paper reviews the international status of the dual purpose cask designed for both transport and storage of spent fuel. Some dual-purpose cask safety related issues, such as supervision, dual-purpose cask safety design features, dual-purpose cask safety research and testing, the crucial issues and the challenges of dual-purpose design and operation, are reviewed. Some countries in the world have successful experience in dual-purpose cask regulatory systems, cask design, cask verification, etc., but there are still some problems that need to be solved. At present, the special legal guidance for dual-purpose casks is still not perfect, and the dual-purpose cask safety design and safety analysis methods need to be further improved.

At present, the capacity of spent fuel treatment and disposal facilities in China is limited, and the total amount of spent fuel in nuclear power plants is increasing, and will exceed the storage capacity of spent fuel pools in the future. Therefore, there is an urgent need to promote the development of China's spent fuel treatment and storage facilities. China is still in its infancy in the development of dual-purpose casks. At the same time, the dual-purpose cask safety supervision experience is insufficient. Therefore, it is urgent to conduct research on the safety design, manufacturing and safety supervision of spent fuel transportation and storage casks by investigating the safety supervision and dual-purpose cask safety design and verification experience in the world. The experience can provide a reference for the development of dual-purpose casks in China.

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