

Suggestion on the safety classification of spent fuel dry storage in China's pressurized water reactor nuclear power plant

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Abstract. China's spent fuel storage in the pressurized water reactors(PWR) is stored with wet storage way. With the rapid development of nuclear power industry, China's NPPs(NPPs) will not be able to meet the problem of the production of spent fuel. Currently the world's major nuclear power countries use dry storage as a way of spent fuel storage, so in recent years, China study on additional spent fuel dry storage system mainly. Part of the PWR NPP is ready to apply for additional spent fuel dry storage system. It also need to safety classificcate to spent fuel dry storage facilities in PWR, but there is no standard for safety classification of spent fuel dry storage facilities in China. Because the storage facilities of the spent fuel dry storage are not part of the NPP, the classification standard of China's NPPs is not applicable. This paper proposes the safety classification suggestion of the spent fuel dry storage for China's PWR NPP , through to the study on China's safety classification principles of PWR NPP in "Classification for the items of pressurized water reactor nuclear power plants (GB/T 17569-2013)", and safety classification about spent fuel dry storage system in NUREG/CR - 6407 in the United States.

1. Introduction

China's NPPs have the problem that the dry storage of spent fuel will not be able to meet the production. In order to ensure the normal operation of the NPP, some NPPs have adopted some temporary measures, such as the transfer and storage of similar units. But, judging from the current trend, the above methods still can't meet the demand of spent fuel output quantity. Spent fuel pools of Dayawan NPP, Qinshan No.2 NPP, Tianwan NPP will reach saturation in 2017 [1]. The nuclear power unit of the above NPPs will face to stop running. Currently, the major nuclear power countries in the world have adopted dry storage as the storage mode of spent fuel, and nearly 70 percent of the NPPs in the United States have built the dry storage system [2]. International practice and experience shows that the spent fuel dry storage system is simple, economical, easy to expand and safe [3].

"The safe evaluation of spent fuel storage facilities" (HAD301/04-1998) [4] defines the dry storage as "in dry storage, spent fuel in the air or inert gas environment. Dry storage facilities include storage of spent fuel in storage tanks, silos or storage rooms. "The comparison of three types of spent fuel storage is shown in table 1.

Items of NPP (systems, equipment and structures) is more important than conventional items to the safety of power plant, thus "safety classification" is referred, which is the concept that classification according to the importance of the safety function. The purpose of classifying safety classification is to



provide classification design criteria. The items of different safety classification are required different for requirements to design, manufacturing, and inspection and testing.

Table 1. Comparison to three ways of spent fuel dry storage

Storage way	Structural features	Shielding way	Heat removal way
(Storage) tanks/(storage)containers	A large volume shielding container for transportation and/or storage of spent fuel. It can be placed in a closed place or in a non-enclosed space.	A metal or concrete tank and a soldered or sealed lining, coat, or top cover	The radiation transfer to surrounding environment and natural or forced convection.
Silos	Ground portable or non-portable structure of storage facilities, containing one or more separate storage chambers. Each storage chamber can hold one or more fuel cells.	It is mainly supplied by structural materials such as steel, cast iron or concrete	Heat exchange by structure shielding material to atmosphere.
Storage rooms	A reinforced concrete building on or below ground, with a storage cavity array. Each storage cavity contains one or more fuel assemblies.	External structures of the storage chamber	Out of heat by circulating air or gas above the outside of the storage cavity; subsequently or directly to the outer atmosphere, or through the secondary exhaust heat system dissipation.

There is also a need for safety classification of spent fuel dry storage facilities in PWR NPP, but there are no relevant regulatory standards in China. Because the spent fuel dry storage facilities are not part of the NPP, it is not applicable to the classification standard of China's NPPs. NUREG/CR - 6407 "Classification for the items of pressurized water reactor nuclear power plants" of USA detailed requires the spent fuel dry storage system safety classification. Many countries in the world refer to NUREG/CR - 6407 to classify spent fuel dry storage safety. However, China's current NPP classification system and NUREG/CR - 6407 classification system has certain differences, therefore, the study of safety classification to China's PWR nuclear power plant spent fuel dry storage facilities is very meaningful. In the spent fuel dry storage in the process of design, construction and maintenance of the project, It makes adaptability of quality and reliability to safety classification, promotes the implementation of the spent fuel dry storage project.

2. Safety Classification of China's PWR

2.1. Classification Method

"Design Safety Regulations of Nuclear Power Plant" (HAF102-2016) [5] requires that must identify all safety important items and classify them according to their function and safety importance. The method of determining the safety importance of safe and important items must be mainly based on the method of certain theory, and assisted by the method of probability theory. The following factors should be considered when using the probability theory method: (1) the safety function of the item performed;(2) the consequences failure to implement of its safety functions;(3) the possibility of carrying out a safety function of the item;(4) the time or duration of a safety function that needs to be performed after the

occurrence of the postulated initiating event. The device performed multiple functions must be classified in accordance with the most important functions they performed.

2.2. Classification Basis

“Classification for the items of pressurized water reactor nuclear power plants” (GB/T 17569-2013) [6] provides classification basis of safety classification in PWR NPP. Classification of safety levels are needed to carry on, because safety classification is to facilitate using the reasonable and differentiated safety design measures. The basis of determining the safety level is the role of item in the following three basic safety functions: control reactivity; discharge core heat; containing radioactive materials and controlling operation emissions and limiting discharge of accidents. The considerations are in line with the requirements of HAF 102-2016.

2.3. Classification Objects

Systems and equipment are usually consisted by many smallest units (parts) performed different safety function. It should determine to divide it into the minimum unit of single level. The smallest unit is the classification object by implementation of classification. Classification objects referred in GB/T 17569-2013 include mechanical components, fuel assemblies and their associated assemblies, electrical components, and structures.

2.4. Safety Level Partition

Table 2 is shown that safety classification partition of different categories of PWR NPP in GB/T 17569-2013. Generally, the items of PWR NPP should be classified to safety classification (SC) and non-safety classification (NC). Special requirements should be identified in NC, namely NC(S) class items. The items classified as NC(S) level are also safe and important, but its failure will not make workers and the public of the factory exceed the prescribed limit. The special requirements of the NC(S) item should be illustrated in the equipment specification. If a single item assumes two or more safety functions, the safety level shall be determined according to its most important safety functions. The safety level of the interface between the pressure mechanical parts is the same as the higher level of the two safety levels of connected items. The interface of electrical equipment should meet the criteria in “Safety Classification Electrical Equipment and Circuit Independence Criteria in Nuclear Power Plant” (GB/T 13286-2008). The safety level of the main supporting part of the equipment shall be the same as the safety level of the supported equipment.

Table 2. Safety Level Partition of Different Categories Items in PWR NPP

Items Categories	Safety Levels and Codes				
	safety important items			non safety important items	
all items	SC			NC	
Supporting mechanical components	SC-1	SC-2	SC-3	NC(S)	common NC
Non supporting mechanical components	SC			NC(S)	common NC
Fuel assemblies and their associated assemblies	SC			non	
Electrical components	SC			NC(S)	common NC
Structures	SC			NC(S)	common NC

Note 1: NC(S) is an item that has special requirements in NC, also named as safety important NC item. For equipment containing radioactive material, NC(S) is equivalent to level 4 of HAD102/03.

Note 2: SC of the electrical component is also known as 1E, and NC is also known as non-1E.

3. Safety Classification of Spent Fuel Dry Storage in US

In NRC Tech-Doc NUREG/CR-6407, spent fuel dry storage components are first identified as either “important to safety” or “not important to safety”. Then, “important to safety” components are further divided into three levels (A, B, or C), depending on the component's importance to safety.

Category A items: belonged to critical to safe operation items. The failures of structures, components and systems included in category A items will directly result in conditions which are adversely affecting to public health and safety. The failure of a single item will lead to loss of shielding leading, cause to release of radioactive materials, or destroy criticality control. Category B items: items have major impact on safety. The failures of structures, components and systems included in category B items will indirectly create a situation adversely affecting public health and safety. The failure of a Category B item, in conjunction with the failure of an additional item, could result in an unsafe condition. Category C items: items have minor impact on safety. The failures of structures, components, and systems will not significantly reduce the storage containers effectiveness and will not be likely to create a situation adversely affecting public health and safety.

4. Suggestion of Spent Fuel Dry Storage Safety Classification in China

Suggestion of main items safety classification in three aspects about mechanical components, electrical components and structures included in PWR NPP spent fuel dry storage facilities in China was put, mainly referred to items classification principle in GB/T 17569-2013, and combined with PWR NPP spent fuel dry storage facility safety functions and structural characteristics, referred classification thinking in NUREG/CR 6407.

4.1. Classification Method

The safe classification method of the spent fuel dry storage in PWR NPP is mainly based on the method of certain theory, and assisted by the method of probability theory, referred to the safety classification method of PWR NPP.

4.2. Classification Basis

The basic safety functions of basis of spent fuel dry storage in PWR NPP are controlling the subcritical state; releasing the heat from spent fuel; containment of radioactive materials. The basis of determining the safety level is the role of item in the three basic safety functions, and considering the consequences of failure to perform its functions, and the time or duration of the item to be put into operation after the postulated initially event.

4.3. Safety Level Partition

Generally, the items of spent fuel dry storage facilities in PWR NPP should be classified to two levels that are safety classification (SC) and non-safety classification (NC). Any item that undertakes the above three basic safety functions, item whose damage will result in accident and other items that have the functions of preventing or mitigating the accident, should be classified as SC; the others are NS.

If a single item assumes two or more safety functions, the safety level shall be determined according to its most important safety functions. Suggestions for the partition of spent fuel dry storage safety levels in PWR NPP are listed in Table 3.

4.3.1. *Safety Classification of mechanism components.* (1) SC-1: belonged to critical components to safe operation. Their failures will directly result in adversely affecting to public health and safety. (2) SC-2: belonged to components that have major impact on safety. Their failures or loss of functions will indirectly create a situation adversely affecting public health and safety. (3) SC-3: belonged to components whose failures will not significantly reduce the system functions. Their failures will not be likely to create a situation adversely affecting operation safety, fuel integrity or public health and safety. (4) NC: belonged to components that have not

effect on safety operation. Their failures or loss functions will not to create a situation adversely affecting operation safety, fuel integrity or public health and safety.

4.3.2. *Safety Classification of electric components.* (1) SC: electrical components needed to prevent, mitigate accidents and protect the public during the accident. (2) NC: electrical components not listed in the safety level.

4.3.3. *Safety Classification of Structures.* (1) SC: items include structures that can contain or storage radioactive materials and whose failure may cause the public or the plant staff to be exposed to the prescribed limit value. (2) NC: structures not listed in SC.

Table 3. Suggestion of Spent Fuel Dry Storage Safety Levels in China

Item Categories	Safety Levels and Codes			
all Items		SC		NC
mechanism components	SC-1	SC-2	SC-3	NC
electric components		SC		NC
structures		SC		NC

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