Fuel Handling Process between Spent Fuel Storage Pools in APR1400 NPPs

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1. Introduction

This paper describes the fuel handling process between spent fuel storage pools in the fuel handling area of auxiliary building for APR1400 Nuclear Power Plants (NPPs). The Spent Fuel Storage Pool (SFSP) in domestic APR1400 NPPs currently under construction is composed of the spent fuel storage pool "A" and pool "B" to accommodate the required storage capability. The spent fuel after being withdrawn from a reactor vessel is stored in the spent fuel storage pool "A" for removal of decay heat, and then transferred and stored to the spent fuel storage pool "B" using the Spent Fuel Handling Machine (SFHM) (Type A) on the SFSP "A", the Spent Fuel Transfer Device (SFTD) at the expanded refueling canal and the Spent Fuel Handling Machine (SFHM) (Type B) on the SFSP "B".

This paper also introduces layout characteristics in fuel handling area, functions and operating areas of each fuel handling equipment and interlocks for safely handling of the spent fuel.

2. Fuel Handling Process between SFSPs

2.1 Layout Characteristics in Fuel Handling Area

The fuel handling system consists of a number of equipment and components to handle a fuel assembly in a safe and reliable manner. Fuel handling is conducted by the Refueling Machine (RM), the SFHM and the Fuel Transfer System (FTS) between the containment building and the fuel handling area of auxiliary building as depicted in Fig. 1. Fig. 1 shows the conventional layout of fuel handling equipment for the previous APR1400 NPPs. The storage pool in Fuel Handling Area (FHA) consists of one for spent fuel and one for new fuel.

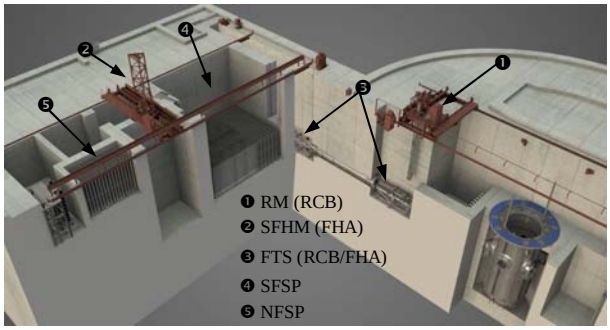

Fig. 1. Conventional layout of fuel handling equipment in previous APR1400

The layout of fuel handling area for APR1400 NPPs has been improved taking into account the plant specific conditions. As shown in Fig. 2, the fuel handling area in domestic nuclear power plants currently under construction is comprised of two spent fuel storage pools. Due to the change of facility layout in fuel handling area compared to that of previous conventional APR 1400 NPPs, the SFHM (Type B) and the SFTD need to be newly adopted, and appropriate fuel handling processes for those equipment are required to develop. In addition, the spent fuel stored in the SFSP "A" is required to be transferred into the SFSP "B" after removal of decay heat.

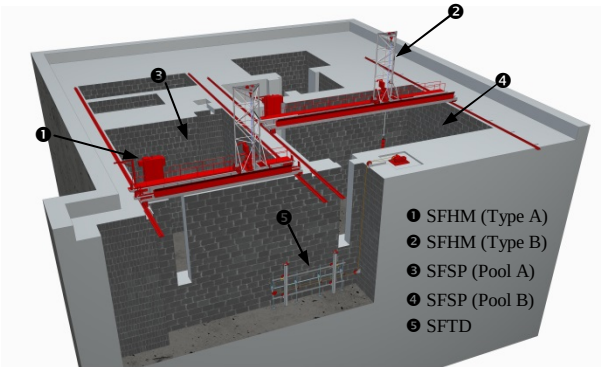

Fig. 2. Layout of fuel handling equipment in current APR1400 under construction

In the fuel handling area, overall fuel handling processes considering layout characteristics of fuel handling equipment for the current APR1400 NPPs under construction are as follows.

For receiving new fuel from shipping container, after arrival of the new fuel shipping containers, the containers are transferred and secured to the operating floor in the new fuel laydown area. The short length new fuel handling tool, attached to the fuel handling hoist, is then locked to a fuel assembly and removed from the shipping container. Then, new fuel is inspected by a new fuel inspection device before placement into the new fuel storage racks. Prior to refueling operations, new fuel is removed from the new fuel storage racks and transferred to the new fuel elevator by using the SFHM (Type A) with an intermediate length new fuel handling tool. The new fuel elevator lowers a fuel assembly into the SFSP "A" to allow the SFHM (Type A) to transfer new fuel to the SFSP "A" (Region I). During refueling operations, new

fuel is transferred to a reactor vessel in the containment building through the fuel transfer tube.

For off-loading from a reactor, spent fuel is transferred to the FTS in the containment building by using the RM. After the spent fuel has passed through the fuel transfer tube, the SFHM (Type A) transports the spent fuel from the FTS transfer carrier and places it into the spent fuel storage racks (Pool "A"). During the spent fuel discharge from the reactor vessel to the SFSP "A", spent fuel assemblies are examined by visual inspection and ultrasonic test in the refueling canal or the spent fuel storage racks (Pool "A").

For shipping spent fuel to shipping cask, the SFHM (Type B) transfers spent fuel from the storage racks (Pool "B") to the spent fuel shipping cask for the intermediate storage. This operation is implemented when the Cask Loading Pit (CLP) is filled with spent fuel storage pool water and the gate between the SFSP "B" and the CLP is opened. After spent fuels are loaded into the cask, the cask is transferred to the cask decontamination pit with the cask handling hoist of the overhead crane. Then it will be transferred to the fuel loading & unloading area with the cask handling hoist for intermediate and/or ultimate storage.

Design characteristics of the fuel handling area for the current APR1400 NPPs under construction compared with those of the previous APR1400 NPPs are summarized in Table 1.

Table 1 : Comparison of design characteristics of fuel handling area between previous and current APR1400

Item		Previous	Current	Remarks
SFSP		1	2	Added SFSP "B"
SFHM		1	2	Added SFHM (Type B)
SFHT*		1	2	Added SFHT for SFHM (Type B)
SFTD		-	1	Newly adopted in current NPPs
Fuel Handling	N/F	SFHM	SFHM (Type A)	N/F : New Fuel S/F : Spent Fuel
	S/F		SFHM (Type A&B)	

* SFHT: Spent Fuel Handling Tool

2.2 Fuel Handling Equipment for Transferring Spent Fuel between SFSPs

The transfer operation of spent fuel between spent fuel storage pools is implemented with the SFHM (Type A) on the SFSP "A", the SFHM (Type B) on the SFSP "B", the SFTD at the expanded refueling canal and the spent fuel handling tools provided in each pool. The followings are functions and operating areas of each fuel handling equipment.

- SFHM (Type A): The basic structure and function of the SFHM (Type A) is a travelling bridge which spans the spent fuel storage pool "A" and moves on rails so as to provide operating area for new and spent fuel storage racks (Pool "A"), the new fuel inspection area, the new fuel elevator, the FTS and the SFTD in fuel handling area.
- SFHM (Type B): The basic structure and function of the SFHM (Type B) is identical to that of the SFHM (Type A). It is a travelling bridge which spans the spent fuel storage pool "B" and moves on rails so as to provide operating area for spent fuel storage racks (Pool "B"), the spent fuel shipping cask, and the SFTD in fuel handling area.
- SFTD: The SFTD, powered by a cable winch, is utilized to transfer spent fuel at the expanded refueling canal between the spent fuel storage pool "A" and pool "B". The SFTD carries the spent fuel by the horizontal movement in a vertical position.
- SFHT: The spent fuel handling tool is used in conjunction with the SFHM (Type A & B) for movement of fuel assemblies among the spent fuel storage pool "A" & "B", the new fuel elevator, the FTS and the SFTD. Two tools are provided. One is stored in a rack within the spent fuel storage pool "A" or refueling canal of fuel handling area and the other is stored in a rack within the spent fuel storage pool "B".

2.3 Interlocks between Fuel Handling Equipment

Fuel handing equipment for transporting spent fuel between spent fuel storage pools includes interlocks to prevent damages to spent fuel assemblies or control components, and to provide for personnel safety during in its operation. The interlocks provided in each fuel handling equipment are as follows.

- Interlocks for the SFHM (Type A & B): The SFHM (Type A & B) has a zone interlock system [1]. Unless the fuel transfer cavity of SFTD is positioned a predetermined location, the entry of the SFHM (Type A & B) into the SFTD's operating zone is prevented by the zone interlock system. This interlock system is provided to prevent collision of both equipment of the SFTD and the SFHM (Type A & B) during transfer operation.
- Interlocks for the SFTD: The SFTD has two interlock systems which are composed of winch overload interlock and translation interlock. If the load of winch drive cable increases above the overload set point, the transfer operation of the SFTD is interrupted by the winch overload interlock system, and when one of the SFHM (Type A) and the SFHM (Type B) is at the refueling canal of the fuel handling area, the transfer operation of the SFTD is denied by the translation interlock system [2].

2.4 Fuel Handling Process for Storing Spent Fuel at the Spent Fuel Storage Pool "B"

In order to handle spent fuel in a safe and reliable manner, various fuel handling equipment are required. Spent fuel transfer operation between spent fuel storage pools in fuel handling area is performed by the SFHM (Type A & B) with spent fuel handling tools and the SFTD. Fig. 3 shows the arrangement of each fuel handling equipment in fuel handling area and the spent fuel handling process between spent fuel storage pool "A" and pool "B".

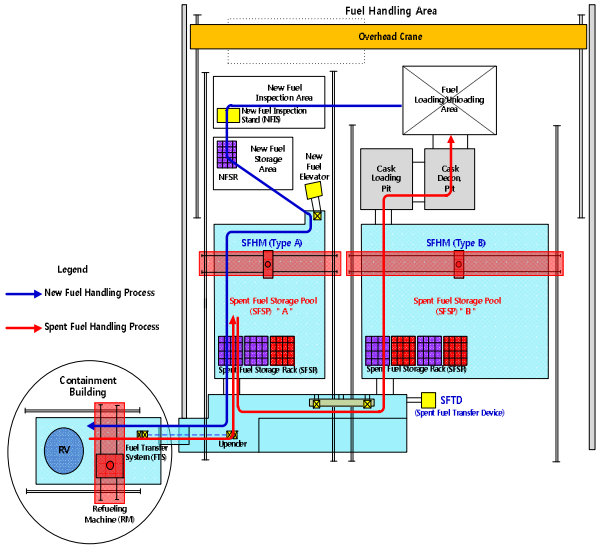

Fig. 3. Fuel handling process of spent fuel between SFSPs

During refueling operations, all spent fuels removed from a reactor vessel are stored in the spent fuel storage pool "A" for removal of decay heat. The spent fuel handling tool, attached to the hoist of SFHM (Type A), is then locked to a spent fuel and removed from the storage racks (Pool "A"). Next, the spent fuel is transferred into the fuel transfer cavity of SFTD at the expanded refueling canal with the SFHM (Type A). At this moment, the fuel transfer cavity shall be located at a predetermined location to allow the SFHM (Type A) approach to the fuel transfer cavity of SFTD. After the spent fuel is loaded into the fuel transfer cavity of SFTD by the SFHM (Type A), the SFHM (Type A) shall be moved into a certain area of the SFHM (Type A)'s operating zone to make the operating condition of SFTD enable.

The fuel transfer cavity of SFTD, powered by a winch cable, is then moved horizontally in a vertical position to the spent fuel storage pool "B" side within the expanded refueling canal. During the movement of the cavity, the SFHM (Type A & B) shall not be approached to the SFTD's operating zone. The SFHM (Type A & B) can only access the transfer cavity when the transfer cavity is at predetermined location. Then, the spent fuel is transferred and stored in a designated location of the spent fuel storage pool "B" by using the SFHM (Type B). The SFTD operation is implemented when the refueling canal is filled with spent fuel storage pool water to allow underwater transportation of the spent fuel.

In addition, the transfer distance of the SFTD is minimized to ensure that the spent fuel is handled in a safe and reliable manner by maximizing the operating zone of SFHM (Type A & B) [2].

3. Conclusions

In order to meet the required storage capability, the spent fuel storage pool in the fuel handling area of domestic APR1400 nuclear power plants currently under construction consists of two spent fuel storage pools ("A" and "B"). The spent fuel removed from a reactor vessel is stored in the spent fuel storage pool "A" for removal of decay heat, and then transferred to the spent fuel storage pool "B" with related fuel handling equipment. In this paper, the fuel handling process and related equipment for transporting spent fuel between spent fuel storage pools are summarized. It is expected that the proposed fuel handling process can be a beneficial suggestion to develop an efficient fuel handling procedure and perform relevant follow-up tasks related to the fuel handling system.

REFERENCES

[1] ANSI/ANS-57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 (Reaffirmed 2005).
[2] I. S. Hwang, et al., Design Features of a Spent Fuel Transfer Device between Spent Fuel Storage Pools in NPPs, Korean Nuclear Society Spring Meeting, 2016.