Comparison of General Arrangement and Design Features of Fuel Handling System

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1. Introduction

This study provides an overview of general arrangement and design features for the fuel handling system operating in Korea. The fuel handling system should be designed to ensure safety functions and to increase efficiency for operation and maintenance during fuel handling. In this study, general arrangement and design features for the fuel handling system are compared to enhance safe and efficient operation. The results of this study can be beneficial suggestion for an optimized design of fuel handling system equipment.

2. Comparison for General Arrangement and Design Features of Fuel Handling System

The fuel handling system (FHS) consists of various equipment and components to handle a fuel assembly in a safe and reliable manner. In this section, design features such as general arrangement, function and interlock system for the Combustion Engineering (CE) FHS and the Westinghouse (WEC) FHS are reviewed. In comparison, typical models of the CE FHS and the WEC FHS operating in Korea are selected and compared.

2-1 General Arrangement of Fuel Handling System

The main equipment of FHS consists of the Refueling Machine (RM), the Spent Fuel Handling Machine (SFHM), the Fuel Transfer System (FTS) and the Upender (UPR) located between the containment building and the fuel handling area of auxiliary building.

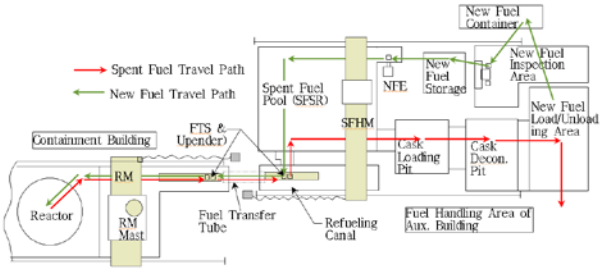

Fig. 1-1 Typical General Arrangement and travel path of the CE Fuel Handling System

A general arrangement and travel path of new fuel and spent fuel for the CE FHS and the WEC FHS are shown on Fig. 1-1 and Fig. 1-2, respectively. In Fig. 1-1 and Fig. 1-2, the RM is used to transport a fuel to and from the reactor and the FTS upender in Containment Building. The SFHM transports a fuel among the New Fuel Elevator (NFE), the Spent Fuel Storage Racks (SFSR) and the FTS upender in refueling canal in the fuel handling area. The CE FHS and the WEC FHS have similar travel path even though there are slightly different general arrangement of the FHS equipment and the buildings.

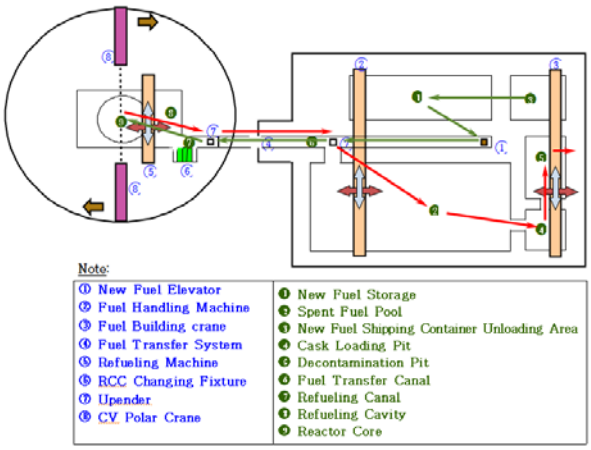

Fig. 1-2 Typical General Arrangement and travel path of the WEC Fuel Handling System

The WEC rod cluster control (RCC) is removed from the spent fuel and put in a new fuel or in a partially spent fuel previously placed in the changing fixture (Refer to ⑥ of Fig. 1-2). Additionally, Ref. 1 provides an optimized general arrangement for the fuel handling system operating in Korea based on the safety functions and efficiency for operation and maintenance.

2-2 Configuration and Function of Component related to the Refueling Machine

In this section, typical configuration and interlock system of the CE RM and the WEC RM operating in Korea are reviewed. The main equipment and components related to the RM are compared in Table I. The design of the WEC RM differs quite substantially from that of the CE RM.

Table I. Comparison of main design features of the Refueling Machine

Equip.	CE Type(Typical)	WEC Type(Typical)
RM	- Bridge, Trolley, Hoist - Mast and rotation mechanism - Hoist Box - Grappler :Rotary Type - Camera: Mounted on the Hoist Box and Tilting function - Spreader	- Bridge, Trolley, Hoist - Outer Mast and rotation mechanism - Inner Mast - Gripper: Finger Latched - Camera: Installed at the bottom of the inner mast - Aux Hoisting Tool Assistance
Min. Water Depth	- 7ft-4in over the top of fuel assembly	- 10ft of over the top of fuel assembly
Interlock system	Zone Interlock : Interfaced with FTS UPR vertical position	Hoist Clear Interlock: Not interfaced with FTS UPR vertical position

Firstly, the CE RM is a traveling bridge and trolley structure, which spans the refueling pool in the containment building. The CE RM mast consists of a tubular stainless structure, which is supported by a rotate bearing on the trolley. The mast can be manually rotated and detented in four location to provide clearance between the core shroud of the reactor vessel. Comparison of component and hoist elevation for the CE RM and the WEC RM is provided in Fig. 2. As shown on Fig. 2, when the CE RM is operating over the reactor, the hoist box is extended out of the mast.

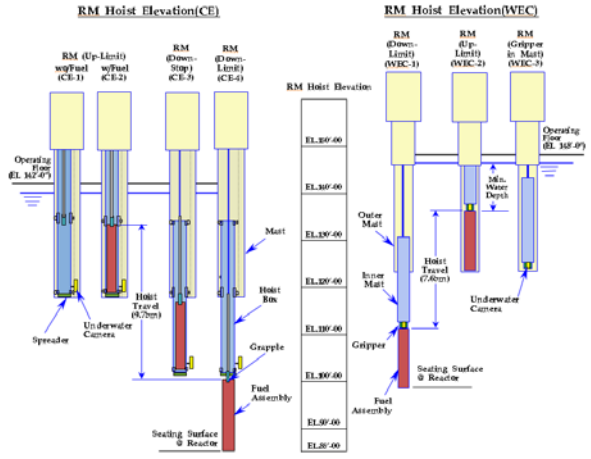

Fig. 2 Typical comparison of components and hoist elevation for the CE and the WEC Refueling Machine

The hoist box is used to align the fuel assembly when it is being inserted or withdrawn from the reactor. The grapple is lowered out of the hoist box and locked onto the fuel assembly. The fuel assembly is then raised into the hoist box and the hoist box raised into the mast. The underwater camera is mounted at the lower end of the hoist box and is tilted from a vertical position by means of an air cylinder. The spreader is a square box component and is used to spread a fuel apart and reduce interference between surrounding fuels and the fuel being handled. Secondly, the WEC RM is also composed of bridge, trolley, and hoist including outer mast, inner mast and gripper assembly. The mast assembly, which is used to maintain alignment of the gripper, provides protection of the fuel assembly and prevents lifting it out of the water. The WEC RM inner mast supports the gripper and raises or lowers the fuel assembly into or out of the outer mast and ensures that the fuel cannot be lifted above the safe-shielding depth of water. The WEC RM gripper has four fingers that are manipulated by a cam and ramp configuration. The RM design includes interlock system to ensure safe handling of a fuel assembly. Operation which could endanger the operator or damage the fuel is prohibited by mechanical or electrical interlocks. The WEC RM control interlock system permits for the machine to travels at hoist up-limit with fuel-loaded or at gripper in mast with fuel-unload. The CE RM has zone interlock system interfaced with the FTS upender to wait at travel limit for FTS upender vertical position. The WEC interlock system can be efficient operation because it does not need to wait at travel limit interfaced to the position of the FTS upender.

2-3 Design Features in Fuel Loading Sequences of the Refueling Machine

The design features in fuel loading sequences of the CE RM and the WEC RM operating in Korea is reviewed. Table II shows the fuel loading sequences for one (1) cycle operation of the RM. The one (1) cycle operation starts at hoist up-limit over the upender and ends at hoist up-limit for next fuel after loading a fuel into the reactor. In the sequences of fuel loading, the WEC RM has design benefits to save fuel hoisting time at the Reactor and the upender due to more simple mechanism and interlock system of the inner mast and the gripper. This mechanism and interlock system would be needed to apply for optimized design.

Table II. Comparison of design features in fuel loading sequences of the Refueling Machine

	Fuel Loading Sequences	Design Features	Remark
1	RM Hoist Up-limit -> Grapple Closed	- (CE) Hoist lowering the Grapple at Up-limit - (WEC) Hoist lowering at the Gripper in Mast with no load	See Fig. 2 (CE-1) See Fig. 2 (WEC-3)
2	Grapple Closed -> RM Hoist Up- limit	(CE) Longer hoisting distance with fuel-loaded	- See Fig. 2 (CE-2) and (WEC-2)
3	FTS Upender -> Reactor	(CE) Longer travel distance from FTS UPR to Reactor	
4	RM Hoist Up-limit -> Auto Stop (Off-Index) at Reactor	(CE) Longer lowering distance at Reactor	- See Fig. 2 (CE-2,4) and (WEC-1,2)
5	Auto Stop (Off-Index) -> Fuel seating at Ractor	(CE & WEC) Same Fuel seating and Off-index operation	
6	Fuel Seating -> Grapple Closed & RM Hoist Up-limit	- (CE) Hoisting the Grapple to Up-limit - (WEC) Hoisting the Gripper at the Gripper in Mast	- See Fig. 2 (CE-1) and (WEC-3)
7	- Reactor -> FTS Upender [Interlock System]	- (CE) Zone Interlock interfaced with the UPR vertical - (WEC) Hoist Clear Interlock not interfaced with the UPR	

3. Conclusion

This study provides an overview of a general arrangement and design features for the fuel handling system equipment operating in Korea. In comparison of FHS equipment, the specific design features such as inner mast operation and the interlock system of the WEC FHS equipment would be efficient for operation and maintenance. The results of this study can be beneficial suggestion for an optimized design of fuel handling system equipment.

REFERENCE

[1] S. G. Chang, et al, Transactions of the Korean Nuclear Society Spring Meeting, 2013, Optimization of General Arrangement for Fuel Handling Equipment in Fuel Handling Area.