Review on Fuel Loading Process and Performance for Advanced Fuel Handling Equipment

Chang, Sang-Gyoon,a Lee, Dae-Hee,a Kim, Young-Baik,a Lee, Deuck-Soo,a
a NSSS Engineering & Development Division, Korea Power Engineering Company, Inc. Daejeon, Korea, sgchang@kopec.co.kr

1. Introduction

The fuel loading process and the performance of the advanced fuel handling equipment for OPR 1000 (Optimized Power Plant) are analyzed and evaluated. The fuel handling equipment, which acts critical processes in the refueling outage, has been improved to reduce fuel handling time. The analysis of the fuel loading process can be a useful tool to improve the performance of the fuel handling equipment effectively. Some recommendations for further improvement are provided based on this study.

2. Analysis for fuel loading processes

The advanced fuel handling equipment consists of various equipment having safety functions and interlocks [1] to handle fuel assemblies safely and should satisfies the performance requirements by transferring rapidly fuel assemblies. The improvements for the fuel handling equipment under construction and in operation have been studied to increase operating efficiency. One of these improvements is to enhance the transferring capability of the equipment from about 2.5 fuel assemblies to more than six (6) per hour during the refueling outage. Figure 1 shows an arrangement and operating zones for the advanced fuel handling equipment in the containment building (CB) and the fuel building (FB).

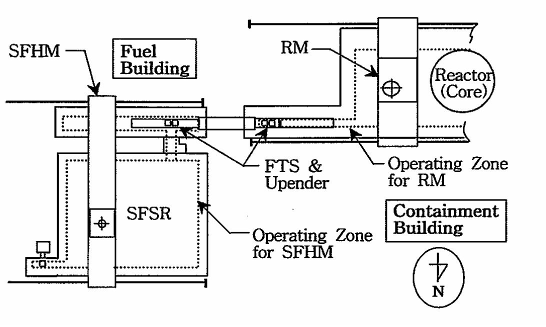

Fig. 1 Arrangement and operation of Advanced Fuel Handling Equipment

For the improvements of the fuel handling equipment, the Personal Computer (PC) data control system based Programmable Logic Controller (PLC) for interlocks and high speed motor drive system are introduced. The off-index operation for the Refueling Machine (RM) hoist is applied during raising and lowering the fuel assembly in the open water region of the core. The zones of simultaneous operations for the bridge and trolley of the RM and the Spent Fuel Handling Machine (SFHM) are expanded to reduce fuel handling time. Figure 2 shows the fuel off-loading and reloading sequences of the fuel handling equipment.

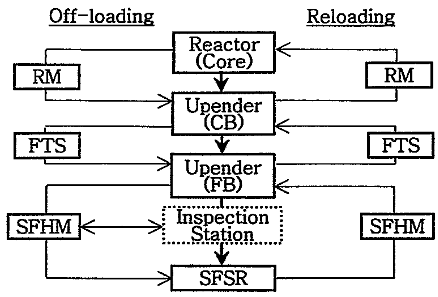

Fig. 2 Off-loading and Re-loading Sequence

During off-loading, the spent fuel removed from the core using the RM is underwater moved and lowered into the empty cavity located in the fuel Transfer System (FTS). The CB upender then rotates the fuel to the horizontal position after which a cable drive transports the transfer carrier through the fuel transfer tube. After the fuel has passed thru the tube, the upender in the FB returns the carrier to the vertical position. The SFHM then removes the fuel from the carrier and transports it to the SFSR after visual inspection of the fuel at the inspection station. The fuel reloading is performed in the reverse of off-loading sequences. It is reasonable to analyze the fuel reloading sequences because the spent fuel inspection sequence in off-loading is generally not considered in the performance evaluation. Studies for fuel reloading process are carried out based on the distance among the center in the core, the fuel transfer tube, and the center of the SFSR. And it is performed based on design parameters of the advanced fuel handling equipment and current zone interlocks [2]. The detailed reloading sequences and their elapsed times for the SFHM are summarized in Table 1. As shown in Table 1, the SFHM reloading cycle is divided into six (6) sequences based on the travel path of the SFHM at the FB.

Table 1 Reloading Sequences and Time Calculation for SFHM

No.	Travel Path	Time (sec)
SFHM-1	Hoist full down & engaged at SFSR	180.2
SFHM-2	Hoist full up (loaded)	
SFHM-3	SFHM move to Upender from SFSR	52.0
SFHM-4	Hoist full down & disengaged at Upender	122.2
SFHM-5	Hoist full up (unloaded)	
SFHM-6	SFHM move to SFSR from Upender	49.0
Total One(1) Cycle Time : 6.72 min		

Elapsed times for the six (6) sequences are shown on Table 1. The time difference between the sum of

SFHM-1 and SFHM-2 at the SFSR and the sum of SFHM-4 and SFHM-5 at the upender is due to the different slow speed zone at each bottom elevation. The elapsed time for the SFHM reloading during one (1) cycle is calculated as 6.72 min. For the FTS reloading, detailed reloading sequences and their elapsed times are summarized in Table 2. Similar methods to the SFHM case are applied to analyze the FTS.

Table 2 Reloading Sequences and Time Calculation for FTS

No.	Travel Path (At Cont. Building) (At Fuel Building)	Time (sec)
FTS-1	SFHM Hoist full down for lowering & up	122.2
FTS-2	Upender up to down at FB(loaded)	184.0
FTS-3	Carriage move to CB Upender	
FTS-4	Upender down to up at CB	
FTS-5	RM Hoist full down for raising & up	91.6
FTS-6	Upender up to down at CB (unloaded)	182.5
FTS-7	Carriage move to FB Upender	
FTS-8	Upender down to up at FB	
Total One(1) Cycle Time : 9.67 min		

The FTS reloading is divided into eight (8) processes for one (1) cycle as shown on Table 2. The elapsed times in FTS-2 thru FTS-4 and in FTS-6 thru FTS-8 are reduced by the improvements of the transfer carrier and the hydraulic pumps of the upender. The elapsed time for the FTS during one (1) cycle reloading is calculated as 9.67 min. The RM reloading is divided into eight (6) sequences. The reloading sequences for the RM are similar to those of the SFHM. The detailed sequences and their elapsed times for the RM are summarized in Table 3.

Table 3 Reloading Sequences and Time Calculation for RM

No.	Travel Path	Time (sec)
RM-1	Hoist full down & engaged at Upender	91.6
RM-2	Hoist full up at Upender (loaded)	
RM-3	RM move to Core from Upender (loaded)	59.0
RM-4	Hoist full down & disengaged at Core	205.6
RM-5	Hoist full up at Core (unloaded)	
RM-6	RM move to Upender from Core	64.0
Total One(1) Cycle Time : 7.00 min		

The elapsed time for the reloading during one (1) cycle is calculated as 7.00 min. The elapsed times in RM-1 and RM-2 and in RM-4 and RM-5 are reduced due to the improvements of the high speed and off-index operation of the RM hoist. The elapsed times in RM-3 and RM-6 are reduced due to the effect of high speed and simultaneous operation of the bridge and trolley.

3. Performance Evaluation

The fuel loading is organically connected and operated with three (3) fuel handling machines. Table 4, which can be taken from the results of Table 1 thru Table 3, shows the number of fuel transferred and the elapsed time per hour for reloading.

Table 4 Performance Evaluation for Reloading of Advanced Fuel Handling Equipment

	Total One(1) Cycle Time (min)(*)	No. of Reloaded Fuel per Hour	Elapsed Time for reloading per Fuel (min)
SFHM	6.72	6.20	18.34
FTS	9.67		
RM	7.00		

(*)For details Unit: Sec

	Hoist (Upender)	Bridge/ Trolley (Carrier)	Waiting Time	Fuel Receiving Time	Total (min)
SFHM	302.4 (52.1%)	101.0 (17.4%)	176.9 (30.5%)	N/A	580.3 (9.67)
FTS	144.5 (24.9%)	222.0 (38.3%)	0.0 (0.0%)	213.8 (36.8%)	
RM	297.2 (51.2%)	123.0 (21.2%)	160.1 (27.6%)	N/A	

It is expected that the advanced fuel handling equipment can transfer 6.2 fuel assemblies per hour. But the detailed acceptance criteria for performance should be determined by the utilities. The total elapsed reloading time per fuel is estimated as 18.34 min. The number of a reloaded fuel per hour is determined by the total time of the FTS, which is calculated to be the longest of all the machines. It means that the RM and the SFHM should wait for the FTS carrier at each building for 160.1 sec (2.67 min) and 176.9 sec (2.95 min), respectively. These results agree with those of Reference [3]. Table 4 indicates that the handling time by the transfer carrier and the fuel receiving time from the RM and the SFHM in the FTS reloading should be considered as dominant factors for more effective operating efficiency.

4. Conclusion

The fuel loading process for the advanced fuel handling equipment of OPR 1000 is analyzed and evaluated in viewpoint of operating efficiency. As the results of this study, it is expected that 6.2 fuel assemblies per hour could be transferred. For more effective operating efficiency, the improve-ments of the transfer carrier and the hoist of the RM and the SFHM should be considered.

REFERENCES

[1] ANSI/ANS-57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 (Re-affirmed 1998).
[2] SKN 1&2 PSAR, Chapter 9.
[3] S. G. Chang, et al, Time Study on Fuel Handling Equipment for KSNP, Korean Nuclear Society Spring Meeting, 2005.