Performance Criteria and Evaluation of Upgraded Fuel Handling Equipment for Operating OPR1000

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1. Introduction

The performance of the upgraded fuel handling equipment for operating 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 meet the performance requirements after upgrade. The results of this study can provide comprehensive understandings and guidelines related to the performance of the fuel handling equipment. Some recommendations regarding performance evaluation are provided based on this study.

2. Performance Criteria

The fuel handling equipment consists of various equipment performing safety functions and interlocks [1] to handle fuel assemblies safely and should satisfies the performance requirements by transferring rapidly fuel assemblies. The fuel offloading and reloading between the Reactor and the SFSR (Spent Fuel Storage Rack) are performing by the RM (Refueling Machine), the SFHM (Spent Fuel Handling Machine), the FTS (Fuel Transfer System) and the Upender in the CB (Containment Building) and the FB (Fuel Building) as shown on Fig. 1.

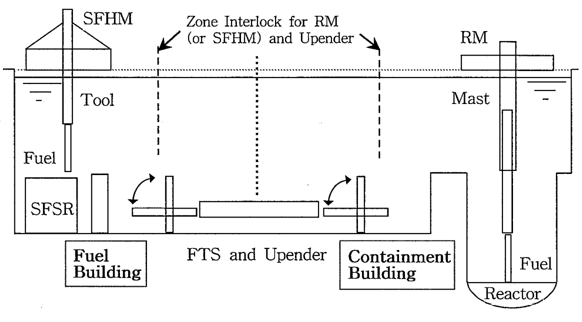

Fig. 1 Arrangement of Fuel Handling Equipment

The performance test for the upgraded fuel handling equipment should be run during the reloading following the installation of the equipment to verify compliance with the performance criteria. This test should be performed for the movement of 20 fuel assemblies from 90th to 109th during the middle of the core reload. The detailed locations for reloading sequence in the Reactor are typically shown on the Fig. 2. Each machine, which consists of the RM, the FTS and the SFHM, should be timed individually during 20 cycle periods. Any time due to irregularities not attributable to the fuel handling equipment could be deducted from the time allotted to that particular cycle.

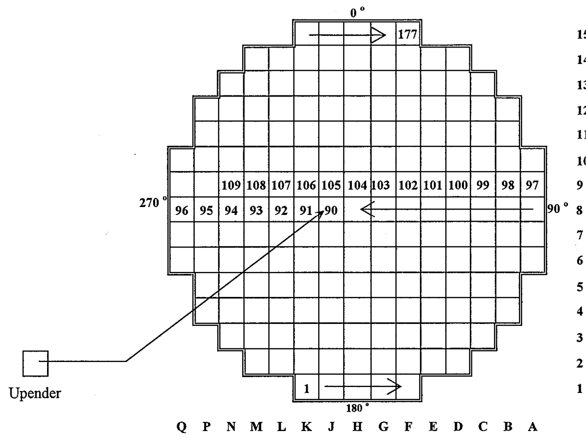

Fig. 2 Reloading Sequence in Reactor

The average time for the 20 cycles should be evaluated according to the criteria as shown on Table 1. The fuel of more than six (6) fuel assemblies per hour should be reloaded and total time for 20 cycles should be transferred within 200 min.

Table 1 Performance Criteria

Reloading (FA/Hour)	Time for 20 Cycles	Level
$N \geq 6.0$	$t \leq 200$ min.	Acceptable
$N < 6.0$	$t > 200$ min.	Unacceptable

3. Performance Evaluation

The improvements for the fuel handling equipment under construction and in operation have been studied to increase operating efficiency. High speed motor and accuracy interlocks control system are introduced in the driving mechanism to reduce the refueling time. The off-index operation for the RM hoist is applied during raising and lowering the fuel assembly in the open water region of the core. The simultaneous travel zones and optimal travel path operations for the bridge and trolley of the RM and the SFHM are also expanded to reduce the refueling time. The fuel loading is organically connected and operated with the combination of three (3) fuel handling machines. The number of a reloaded fuel per hour can be determined by the one cycle time of the FTS, which was calculated to be the longest among three (3) machines [2]. It is reasonable to analyze the FTS reloading sequences in this view-point. The one (1) cycle reloading for FTS is divided into eight (8) sequences based on the travel path in two (2) buildings. The detailed reloading sequences and their elapsed times for the FTS are summarized in Table 2.

Table 2 Elapsed Time of Reloading Sequences for FTS

Seq. No. (SN)	Reloading Sequences for FTS	Fuel at Upender	Time (sec)
1	SFHM Hoist Down to Up at Upender(*)	Loading	85.0
2	Upender Up to Down at FB	Loaded	55.0
3	Carriage moved to CB	Loaded	63.6
4	Upender Down to Up at CB	Loaded	65.3
5	RM Hoist Down to Up at Upender(*)	Unloading	139.5
6	Upender Up to Down at CB	Unloaded	62.3
7	Carriage moved to FB	Unloaded	63.9
8	Upender Down to Up at FB	Unloaded	59.1
	Total One(1) Cycle Time : 9.89 min.		593.7

Note (*) : w/o zone-interlock for RM (or SFHM) and Upender

The elapsed times in the SN-2 thru SN-4 and the SN-6 thru SN-8 are reduced by upgrading the drive motor of the transfer carrier and the hydraulic pumps of the upender. In the SN-2, 4 and SN-6, 8, which indicate up and down of the upender at each building, the SN-4 took 65.3 sec to rotate the upender from down to up position with fuel loaded condition. The elapsed time of 20 ~ 40 sec was decreased as compared with the previous one before upgrading. The elapsed times of the SN-3 and SN-7, which indicate the carriage moving between two buildings, were measured as 63.6 sec and 63.9 sec, respectively. These times were also decreased about 25 % as compared with the previous ones before upgrading.

The SN-1 and the SN-5 indicate the insert and withdraw of a fuel assembly by the SFHM and the RM at each upender, respectively. The elapsed time of 85 sec for the SN-1 was shorter than that for the SN-5, which was 139.5 sec. It is thought that the RM hoist travel is longer than that of the SFHM and the hoist slow zone within the upender of the reactor side is longer than that of the pool side. The zone interlock exists between the RM (or the SFHM) and the upender for OPR 1000 [1]. This interlock should be considered in the SN-1 and the SN-5, which will be one of the factors to determine the performance of the upgraded fuel handling equipment. In case of having the zone interlock, the upender is only allowed to rotate after the RM (or the SFHM) is located away certain distance from the upender at each building as shown on Fig. 1. The elapsed time for total one (1) cycle reloading as shown on Table 2 was measured as 593.7 sec (9.89 min) for the movement of 20 fuel assemblies when not considering the zone interlock between the RM (or the SFHM) and the upender. From this measuring data, the upgraded fuel handling equipment was evaluated to meet the performance criteria as shown on Table 3. It is expected that the upgraded fuel handling equipment can reload more than 6 fuel assemblies per hour and transfer 20 fuel assemblies within 200 min. When the eight (8) reloading sequences of Table 2 are divided into three (3) categories, such as upender operating time, carriage operating time and the RM and the SFHM fuel handling time at the upender, the detailed elapsed time and percentage for one (1) cycle for each category are shown on Table 3.

Table 3 Performance Evaluation for Reloading of Upgraded Fuel Handling Equipment

One(1) Cycle Time (min.)(*)	No. of Reloaded Fuel per Hour	Time for 20 Cycles (min.)
9.89	6.07 > 6.00	197.9 < 200.0

(*) for details : Unit: sec

	Upender Operating Time	Carriage Operating Time	Handling Time at Upender	Total (min.)
SN of Table 2	SN-2,4, 6,8	SN-3,7	SN-1,5	593.7 (9.89)
Elapsed Time (%)	241.7 (40.7 %)	127.5 (21.5 %)	224.5 (37.8 %)	

As shown on Table 3, the transfer upender operating time and the RM and the SFHM fuel handling time at the upender should be considered as dominant factors to determine the performance for upgraded fuel handling equipment.

4. Conclusion

The performance of the upgraded fuel handling equipment for operating OPR 1000 are analyzed and evaluated. As the results of this study, it was measured that more than six (6) fuel assemblies per hour could be reloaded at the condition without the zone interlock and transferred 20 fuel assemblies within 200 min. However, for OPR 1000, the elapsed time to be caused from the zone interlock should be considered as a factor to determine the performance of the upgraded fuel handling equipment.

REFERENCES

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