Time Study on Fuel Handling Equipment for KSNP

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1. Introduction

It is currently required to improve performance of the fuel handling equipment for increasing operating efficiency at nuclear power plants. The sequence and elapsed time from the core to the fuel rack during fuel off-loading for the Korean Standard Nuclear Power Plant (KSNP) are analyzed. An improvement scheme for the fuel handling equipment can be provided based on the results of time study. It is an effective measure to improve performance of the fuel handling equipment because the improvement is accompanied by reduction of radiation exposure for operators from a safety viewpoint.

2. Time study for fuel off-loading sequence

The fuel off-loading is performed by the fuel handling equipment in the containment building (CB) and the fuel building (FB). The fuel handling equipment consists of various equipment and tools having safety functions and interlocks to handle fuel assemblies safely. The fuel assembly, which is hoisted and transferred by the Refueling Machine (RM) in the containment building, is transferred through the fuel transfer tube by the Fuel Transfer System (FTS) and stored into the fuel rack by the Spent Fuel Handling Machine (SFHM) in the fuel building. Interlocks between the fuel handling equipment are installed to secure a safe operation during the fuel handling. The fuel off-loading sequence and its time study are shown in Figure 1.

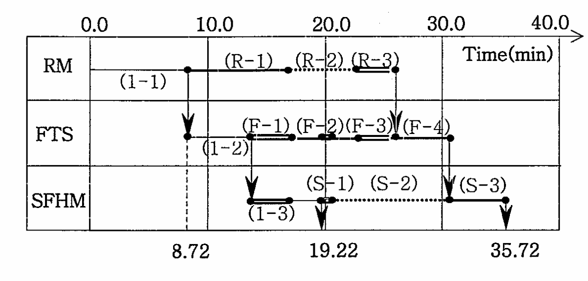

Figure 1. Fuel off-loading sequence for KSNP

Figure 1 shows that the steps of (1-1), (1-2), and (1-3) are performed by the RM, the FTS and the SFHM, respectively for the first fuel assembly off-loaded from the core. The time study for the second fuel off-loading is reviewed as a sample of this analysis. The results of time study after the second fuel off-loading are the same as the second ones. Detailed sequences for the fuel handling equipment during the second fuel off-loading are thus described. The off-loading sequences performed by the RM in the containment building can be separated as follows; (1) to move to the core and hoist a fuel assembly up to the up-limit and transport it to the FTS, (2) to wait in the FTS zone until the FTS cavity is rotated to the vertical position, and (3) to insert a fuel assembly into the FTS cavity. The sequences performed by the FTS after receiving the fuel assembly into the FTS cavity can be separated as follows; (1) to rotate the FTS cavity containing the fuel assembly and transport it to the fuel building (2) the fuel assembly unloaded from the FTS cavity using the SFHM, (3) to rotate the empty FTS cavity and transport it to the containment building, and (4) another fuel assembly loaded into the FTS cavity using the RM. The sequences performed by the SFHM in the fuel building can be separated as follows; (1) to hoist the fuel assembly from the FTS cavity and store it into the fuel rack, (2) to move to the FTS zone, and (3) to wait in the FTS zone until the FTS cavity is rotated to the vertical position. The time study during the fuel off-loading is carried out based on the distance among the reactor vessel, the fuel transfer tube and the fuel rack. This study is also performed based on performance parameters [1] of each fuel handling equipment and interlocks [2] for the KSNP design. Detailed time results during the second fuel off-loading sequence are summarized in Table 1.

Table 1. Time study during fuel off-loading

	Step	Time (min)	Traveling Path
RM	R-1	8.36	Moves FA from core to FTS
	R-2	5.70	Waits in FTS Zone
	R-3	2.44	Inserts FA into FTS cavity
FTS	F-1	3.06	Interlocks with SFHM
	F-2	5.50	Moves FTS cavity from FB to CB
	F-3	2.44	Interlocks with RM
	F-4	5.50	Moves FA from CB to FB
SFHM	S-1	1.74	Moves tool from fuel rack to FTS
	S-2	9.76	Waits in FTS Zone
	S-3	5.00	Stores FA into fuel rack

In the process of the second fuel off-loading, the Steps (R-1), (R-2), and (R-3) are performed by the RM and their elapsed time results are calculated as 8.36 min, 5.70 min and 2.44 min, respectively. The Steps (F-4) and (S-3) performed by the FTS and the SFHM take 5.50 min and 5.00 min. The Steps (R-3) and (F-3) are operated with interlocks between the RM and the FTS and their elapsed time are calculated as 2.44 min. The same interlocking practices are applied for the Steps between (F-1) and (1-3) and the Steps between (S-1) and the middle of (F-2) as shown in Figure 1. The Steps (R-2) and (S-2) are required for the RM and SFHM to wait for 5.70 min and 9.76 min, respectively, until the FTS carrier gets back. Based on Table 1, the total time to move a fuel assembly for the fuel off-loading to the fuel rack from the core is calculated as 27.00 min.

3. Evaluation on time study during fuel off-loading

As the result of the time studies for the KSNP, the total elapsed time for one (1) off-loading cycle done by the RM can be calculated to be 16.50 min and 3.39 Fuel Assemblies (FAs) per hour are consequently estimated to be off-loaded from the core. The time for one (1) off-loading cycle done by each fuel handling equipment can be calculated to be the same as that of the RM. It is necessary to scrutinize systematically the fuel handling sequence to reduce the fuel off-loading time because they are operated with interlocks each other. The total off-loading time is classified into the operating time, the interfacing time and the waiting time for the RM, the FTS and the SFHM as shown in Table 2.

Table 2. Elapsed time classification for fuel handling equipment

	Operating Time (min)	Interfacing Time (min)	Waiting Time (min)
RM	8.36	2.44	5.70
FTS	9.26	7.24	0.00
SFHM	1.94	4.80	9.76

The operating time is a period that the fuel handling equipment moves and hoists a fuel assembly without interfacing other equipment. The interfacing time is a period that two (2) of the equipment are operated together. The waiting time is a period that the RM and the SFHM wait for the FTS cavity in the FTS zone. As shown in Table 2, the improvement of the FTS should be reviewed primarily to reduce waiting times (Steps: R-2 and S-2) of the RM and the SFHM and also improve-ments of the RM and the SFHM can reduce the off-loading time by shortening Steps (R-1), (R-3) and (S-3). The number of off-loading fuel assemblies per hour depending upon the improvement scheme of these equipment is shown in Figure 2. Case 1 shown in Figure 2 is only for increasing the speed of the FTS. Case 2 is for increasing the speed of the RM and the FTS and Case 3 for all of the RM, the FTS and the SFHM. The off-loading in Case 1 is estimated to handle 5.34 FAs per hour and the elapsed time during one (1) off-loading cycle can be reduced to 10.68 min. The number of off-loaded FAs in Case 2 and Case 3 can be increased to 6.47 FAs and 7.66 FAs per hour, respectively. The elapsed time during one (1) off-loading cycle in Case 2 and Case 3 can be reduced to 8.76 min and 7.45 min, respectively. In the time study, the number of off-loaded FAs in Case 1 can be increased 58 % compared to that of the KSNP by increasing the speed of the FTS and the maximum 7.66 FAs per hour can be off-loaded by improving all of the three (3) fuel handling equipment.

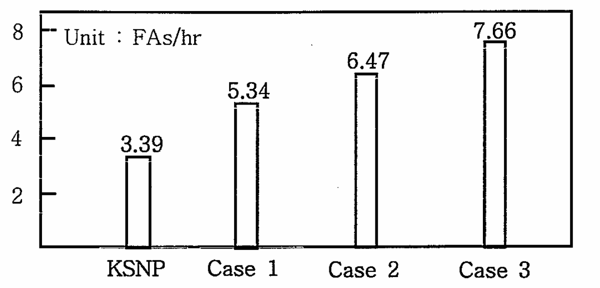

Figure 2. Off-loading FAs depending upon improvement of fuel handling equipment

In this paper, the number of off-loading FAs based on the arrangement and performance of the fuel handling equipment were reviewed. In order to reduce additionally the off-loading time, further detailed review on improving operating conditions and design parameters for the fuel handling equipment will be necessarily required.

4. Conclusion

Time studies for fuel off-loading from the core were carried out on the basis of the arrangement and the existing fuel handling equipment for the KSNP. The elapsed time during one (1) off-loading cycle was estimated to be 16.50 min, which is equivalent to handle 3.39 FAs per hour. From the case study when the advanced fuel handling equipment, which is designed using a state-of-the art technology, is applied to the KSNP it is turned out that about 7 FAs per hour can be transferred from the core. Resulting from applying the advanced fuel handling equipment to the KSNP operating efficiency of the plant will be increased by reducing the refueling time and accompanied by reduction of radiation exposure during the refueling outage.

REFERENCES

[1] Feasibility Study for Yonggwang Units 1,2 Fuel Handling Equipment Modifications, KHNP, 2004. 10.

[2] YGN 3&4 FSAR, Chapter 9.