Analysis of Behavior of SFP in Case of LOSFPC Accident Using MAAP5 Code in Pressurized Light Water Reactor (OPR1000)

Dae Hyung Lee, Ki Taek Kim, Jae Yul Kim
[a]*KEPCO E&C, Power Engineering Research Institute, 269 Hyeoksin-ro, Gimcheon-si, 39660*
[*]*Corresponding author: bigbro@kepco-enc.com*

1. Introduction

Verification and improvement studies are underway to ensure the prevention of release of fission product to environment from spent fuel pool (SFP) after the Loss of Spent Fuel Pool Cooling (LOSFPC) accident.

The amount of heat generated by the single fuel assembly in the SFP is small, but the amount of heat generated by accumulated assemblies is large because there are lots of spent fuel stored during plant power operation. In addition, since there is no long-term individual storage facility of spent fuel in Korea, SFPs in Korean nuclear power plants have been expanded in size or designed in a dense manner, and the assembly is designed to extend the fuel usage period and allow more combustion. In Korea, we use dense storage bases with high storage densities in wet storage facilities capable of removing large amounts of residual heat.

When the SFP cooling pump is stopped and the cooling and makeup functions are lost due to Station Black Out (SBO), Extended Loss of AC Power (ELAP) or Loss of Supporting System, the water in the SFP will boil and the fuel assemblies will be exposed to the air. As a result, cladding temperature increases and then spent fuel can be damaged. This accident results in releasing an amount of fission product to environment from the spent fuel in pool.

Therefore, it is important to prevent the spent fuel from being exposed to the atmosphere. To prevent this accident, SFP evaporation assessment should be conducted. Heat load calculation by EPRI methodology with conservative postulates can't analysis the behavior of SFP after exposure of the fuel. [1]

However, in this paper, to understand the accident behavior due to the fuel exposures, behavior of the plant model would be analyzed by using the MAAP5 code based on the loss of the SFP cooling function and the supply of replenishing water. Comparing with design calculation by EPRI methodology, more realistic result is derived from MAAP5 analysis. This result shows that the SFP has been designed with sufficient margin.

2. Methods

2.1 Considerations

The flow chart of the accident in the case of the loss of the SFP cooling is as follows [1]. (Fig. 1.)

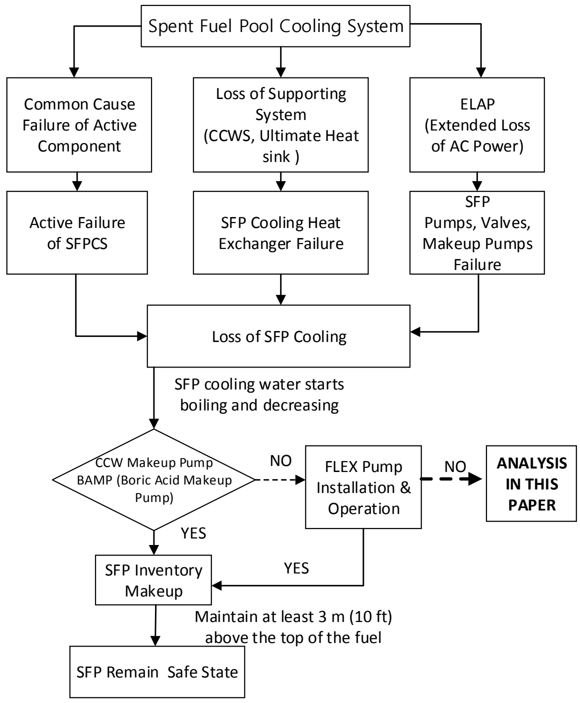

Fig. 1 Flow Chart of the LOSFPC

To analyze the behavior of SFP in loss of cooling accident, following analysis was conducted with excluding the SFP cooling and water makeup functions

- SFP water inventory & decay heat
- SFP boiling time
- Spent fuel exposure time
- SFP water level change depending time
- Spent fuel melting time

2.2 Analysis using MAAP5

Design information of OPR1000 was incorporated to simulate loss of SFP cooling accident. Unlike design calculation or EPRI methodology of spent fuel decay heat [2], detail design information such as fuel cycle, cooling time, burnup cycles, initial uranium enrichment and mass was input to MAAP5, so that MAAP5 calculated the decay heat [3]. In order to make conservative accident model, refueling operation was considered with 19 batches of 68 previously stored assemblies and the offloaded full core (177 assemblies), which was immediately offloaded after 100 hours of reactor shutdown.

Table 1 Inputs

Reactor Thermal Power	2,825 MWT
Refueling Cycle	18 months
# of Refueling Fuels	(68/177) assemblies
Initial Water Temp	333 K (140 ˚F)

3. Results

As SFP cooling system is lost, water is getting hotter and eventually start to boil (at 4.95 hours after accident). When the water gets the saturation temperature, all the residual heat is used to boil the water. So that, until the water is completely evaporated, the temperature remains constant. (Fig. 2) After water depleted (about 94 hours after accident), the water temperature has no meaningful values because water level is far below the heat source (fuel rack) and almost no water remains.

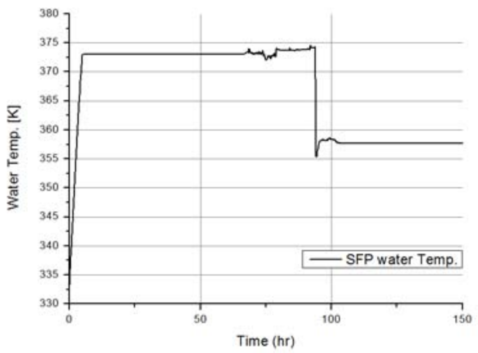

Fig. 2 SFP Water Temperature

The change of water level in SFP is shown in Fig. 2, and event time is listed on Table 2.

It takes 4.95 hours to start boiling water, and 47.36 hours to reduce the water level to the top of the fuel, and the fuel is completely exposed after 67.82 hours.

Table 2 Time lap according to water level

Boiling Time	4.95 (hr)
Time for 3 m (10 ft) above the fuel top	28.03 (hr)
Time to Uncover	47.36 (hr)
Time to Fully Uncover	67.82 (hr)

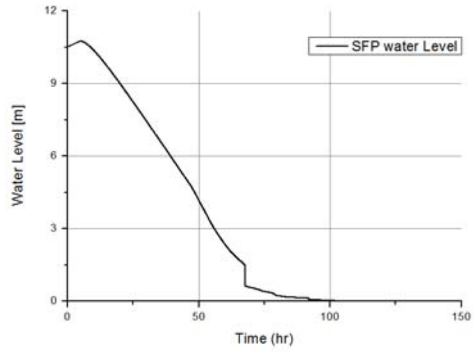

Fig. 3 SFP Water Level

Once the spent fuel is exposed, the cladding temperature begins to increase. As the fuel is completely exposed, the temperature of the cladding rises rapidly and the fuel gets melted.

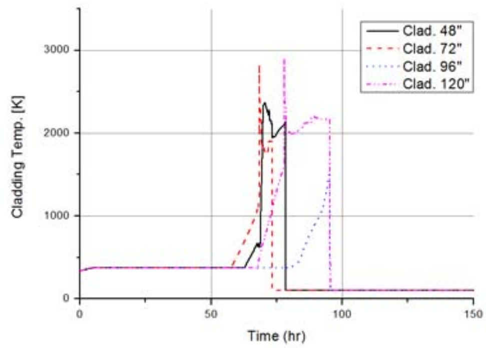

Fig. 4 Cladding Temperature

Fig. 4 shows the temperature of some claddings different in elevations. They are heated up after fuel is exposure and as they get above 1,478 K (2,200 ˚F), at which the fuel is considered to be damaged.

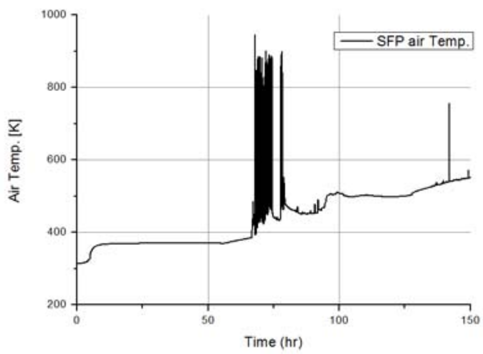

Fig. 5 SFP Comp. Temperature

Fig. 5 shows the temperature change of the SFP compartment. The temperature is kept constant until all the cooling water evaporates, but as the cooling water is depleted, the temperature rises continuously.

4. Conclusions

According to the analysis of MAAP5, it takes 4.95 hours until water boiling, 47.36 hours to fuel exposure, and 67.82 hours to fuel melt after the loss of SFP cooling. Therefore, it is needed to supply makeup water to SFP for prevention of release of fission product from SFP to environment within 47.36 hours.

In the case of OPR1000, the realistic analysis result with using MAAP5 is analyzed to have sufficient response time.

ACKNOWLEDGEMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20151510101780)

REFERENCES

[1] KHNP, Evaluation Report for DEC Coping Capability, S15LM03-E-2-TR-015R0, 2017.

[2] Electric Power Research Institute, Inc., Spent Fuel Pool Accident Characteristics, 2013

[3] Electric Power Research Institute, Inc., MAAP 5 User's manual, 2008.