Preliminary Calculation on a Spent Fuel Pool Accident using GOTHIC

Jaehwan Park [a*], Yu Jung Choi [a], Tae Hyub Hong [a], Hyeong-Taek Kim [a]
[a] *KHNP-CRI, 70,1312-gil, Yuseong-daero, Yuseong-gu, Daejeon,305-343*
[*] *Corresponding author: park.jaehwan@khnp.co.kr*

1. Introduction

A spent fuel pool contains a large amount of cooling water to store spent fuel, but the decay heat generated from spent fuel is much lower than the energy from the fuel loaded in the reactor core. The probability of an accident happening at the spent fuel pool was believed to be quite low until the 2011 Fukushima accident occurred. Notably, large amount of spent fuel are normally stored in the spent fuel pool for a long time compared to the amount of fuel in the reactor core and the total heat released from the spent fuel is high enough to boil the water of the spent fuel pool when the cooling system does not operate. In addition, the enrichment and the burnup of the fuel have both increased in the past decade and heat generation from the spent fuel thereby has also increased. If an accident occurred, the damage could be serious because the spent fuel pool is located outside of the containment and a large amount of spent fuel is stored in it [1].

The failure of the cooling system at the spent fuel pool (hereafter, a loss-of-cooling accident) is one of the principal hypothetical causes of an accident that could occur at the spent fuel pool. In this paper, the preliminary calculation of a loss-of-cooling accident was performed.

2. Methods and Results

2.1 Accident Scenario

For the calculation of a loss-of-cooling accident, the following conditions were assumed: the cooling system is disabled and no actions for recovery of the cooling system are conducted. The model was calculated with GOTHIC 8.1 computer code for a period of roughly a week after the occurrence of the postulated accident [2]. GOTHIC code provides detailed thermal-hydraulic information under various conditions of the spent fuel pool.

2.2 Modeling of Spent Fuel Pool

This model was designed on the basis of APR1400 design information. Fig.1 shows a schematic design of the GOTHIC model for a loss-of-cooling accident. The model has two control volumes, the volume for the spent fuel pool and the empty volume above the spent fuel pool inside the building, the size of which is roughly double that of the spent fuel pool. The latter volume is occupied by air. 95 % of the spent fuel pool is filled with cooling water as the initial temperature of 80 ˚F and the rest is air.

Spent fuel and the spent fuel rack were designed as a thermal conductor. It is assumed that 1,000 spent fuel assemblies, taking into account the capacity of the spent fuel pool storage and the designed life, are stored in the pool when the postulatied accident initiated. Decay heat released from the spent fuel in the pool is assumed as approximately 7.06 MW, referring to another research paper for the spent fuel pool accident analysis [3].

Spent fuel racks were designed roughly as steel plates. The role of spent fuel racks as a heat sink is not significant but spent fuel racks should be included in the model in order to accurately calculate the amount of water in the pool.

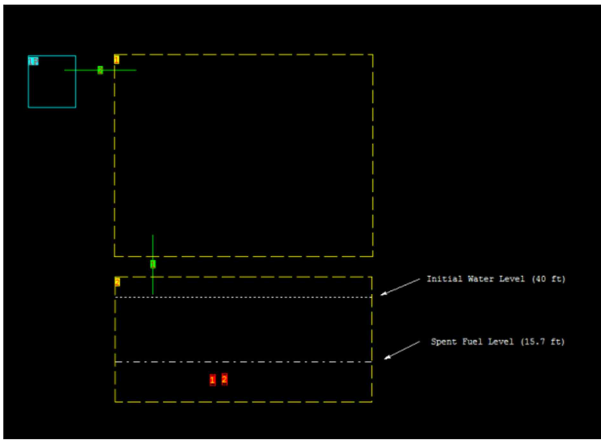

Fig. 1. Schematic design of GOTHIC model for loss-of-cooling accident of spent fuel pool

2.3 Calculation Results

From the results of the calculation, the water at the storage pool boiled away and the spent fuel was exposed. Fig.2 shows the water temperature of the spent fuel pool. The temperature of water increased immediately after the accident and reached a saturation point after about one hour passed.

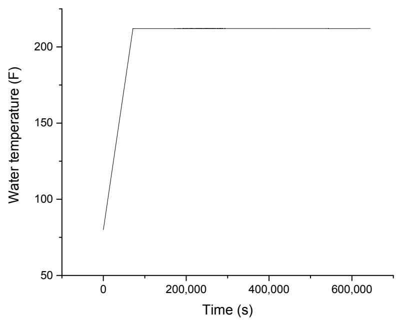

Fig. 2. Water temperature of loss-of-cooling accident

The water level of the spent fuel pool is presented in Fig. 3. The water level rose initially until the water temperature reached the saturation point because of thermal expansion of structures in the pool. After about 100 hours, the fuel assemblies began to become uncovered, which is the most important point in a loss-of-cooling accident. Once the fuel assemblies are uncovered, cooling with natural circulation along the spent fuel racks is no longer possible. The water completely boiled away in about 150 hours.

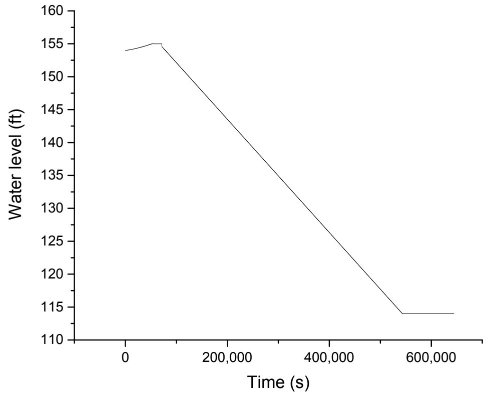

Fig. 3. Water level of loss-of-cooling accident

3. Conclusions

In this paper, the preliminary calculation of a loss-of-cooling accident was performed with GOTHIC. The calculation results show boiling away of water in the spent fuel pool due to the loss-of-cooling accident and similar thermal performance of the spent fuel pool with previous research results. Based on the results, accurate modeling and calculation including heat transfer between spent fuels in the pool and proper prediction of the decay heat would be performed to analyze the thermal performance of the spent fuel pool in detail.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Research & Development of the Institute of Energy Technology and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry & Energy. (No.20141510101670)

REFERENCES

[1] NEA/CSNI/R(2015)2, Status Report on Spent Fuel Pools under Loss-of-Cooling and Loss-of-Coolant Accident Conditions, Nuclear Energy Agency, 2015

[2] GOTHIC Thermal Hydraulic Analysis Package User Manual Version 8.1(QA), Electric Power Research Institute, 2014

[3] Xiaoli Wu, Wei Li, Yapei Zhang, Wenxi Tian, Guanghui Su, Suizheng Qiu, Analysis of the loss of pool cooling accident in a PWR spent fuel pool with MAAP5, Annals of Nuclear Energy 72, pp. 198-213, 2014

[4] Regulatory Guide 3.54, Spent Fuel Heat Generation in an Independent Spent Fuel Installation (Rev. 1), United States Nuclear Regulatory Commission, 1999

[5] NUREG/CR-6999, Technical Basis for a Proposed Expansion of RG-3.54 – Decay Heat Generation in an Independent Spent Fuel Storage Installation, United States Nuclear Regulatory Commission, 2010