Containment Pressure and Temperature Analysis due to Sodium-induced Fire using CONTAIN-LMR

Jun Heo *, Jaesik Jeung
KEPCO E&C, 269 Hyeoksin-ro, Gimcheon-si, Gyeongsangbuk-do, 39660, Republic of Korea
**Corresponding author: jheo@kepco-enc.com*

1. Introduction

Prototype Gen-IV Sodium-cooled Fast Reactor (PGSFR) has several sodium containing systems inside the containment. The liquid sodium is used as a coolant of PGSFR. The sodium-induced fire occurs when it contacts oxygen. This can challenge containment integrity due to the pressure and temperature increase and also produce aerosol which can degrade the performance of safety-grade equipment by chemical attack.

In PGSFR, the piping failure does not occur since the piping inside the containment is designed as double-walled. Nevertheless, the sodium-induced fire accident inside the containment should be analyzed to determine the containment design pressure and temperature.

In this paper, the containment pressure and temperature (P/T) responses due to sodium-induced fire are described. To evaluate this event, the CONTAIN-LMR code is used.

2. Analysis Methods and Results

In this section, the methodologies and assumptions to simulate sodium-induced fire inside the containment are described.

2.1 Assumptions

Due to lack of the data, some of the input parameters such as the total amount and surface area of the sodium spillage and its surface area are conservatively assumed in view of peak temperature and pressure and its details are as follows;

- A guillotine break is assumed on the Intermediate Heat Transfer System (IHTS) piping.
- A total amount of sodium contained in the IHTS is assumed to release to the containment.
- The type of a sodium fire is modeled as a pool fire and the sodium surface area exposed to oxygen inside the containment is the same as that of a compartment containing the sodium spillage under the condition of well spreading.
- The containment Heating, Ventilation and Air Conditioning (HVAC) system is operated to refrigerate and recirculate the normal containment atmosphere. However, it is not performed for the safety function at accident. Thus, the heat removal by containment HVAC at the analysis of containment pressure and temperature is not considered and there is no external source of oxygen.

2.2 Modeling

Fig. 1 illustrates the nodalization of the containment model developed by use of the CONTAIN-LMR computer code. The model consists of eleven (11) cells and twelve (12) flow paths between the cells. The volume in the same level in containment is identically divided into two cells to estimate the flow circulation and the flow paths are based on the design specification such as doors and stairs.

The heat structures such as floors, walls and ceilings of this model are composed of steel liner and concrete.

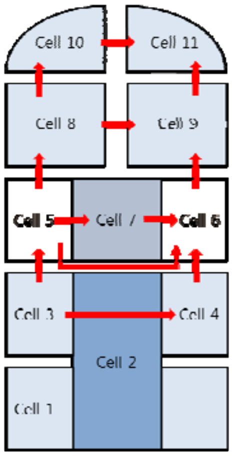

Fig. 1. CONTAIN-LMR Nodalization for PGSFR Sodium Fire Analysis

2.3 Accident Scenario

The leaked sodium is assumed to spread well into the surface area of a compartment where the break is assumed. The sodium effluent through the break is discharged evenly into Cell 5 and Cell 6 in Fig.1

2.4 Results

The sodium-induced pool fire occurred in the annulus area inside the containment is analyzed by CONTAIN-LMR code. Fig. 2 shows the cell pressure transients. The peak pressure is reached to 19 psia, approximately. The pressure of Cell 1 and Cell 2 is not increased since they are not included in the containment pressure boundary and there are no any flow paths. Fig.

3 shows the results of cell temperature. The peak temperature is approximately reached to 320 ℃. It is expected that the integrity of concrete structure and equipment is declined. Fig. 4 shows the sodium pool temperature during the transients and its peak values at Cell 5 and Cell 6 are increased up to 620 ℃ and 600 ℃, respectively. As shown in Fig. 2 and Fig. 3, the containment pressure and temperature initially increase and reach the peak value. And they subsequently decrease because the heat generation rate is decreased by the depletion of oxygen inside the containment and the heat is transferred into the heat structures such as the floors, walls and ceilings.

Fig. 5 shows the oxygen mole fraction of each cell. After sodium-induced fire, the oxygen mole fraction of each cell is gradually decreased except for Cell 1 and Cell 2. Fig. 6 and Fig. 7 show the floor temperature of Cell 5 and Cell 6. As shown in Fig. 6 and Fig. 7, the peak temperatures of liner plate (F_L1) and concrete (F_C1) are estimated to 450 ℃ and 370 ℃, respectively. During the accident, heat absorbed to the concrete evaporates the free water contained in the concrete, and which may potentially weaken the strength of the concrete and steel liner plate.

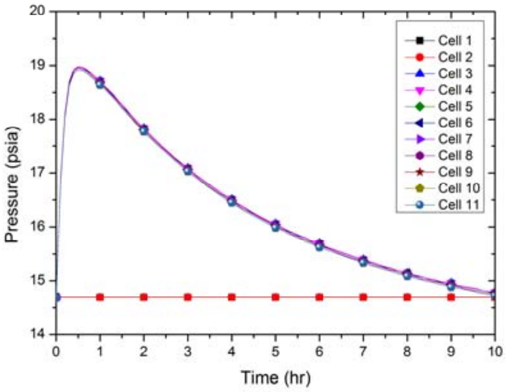

Fig. 2. Cell Pressure

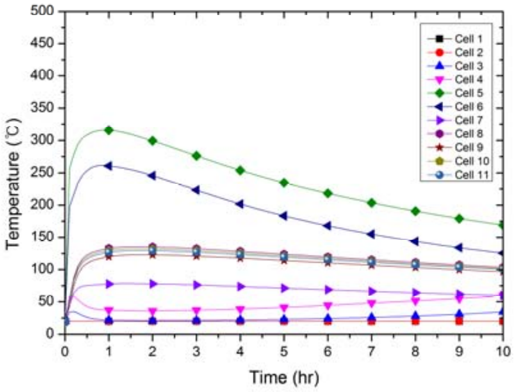

Fig. 3. Cell Temperature

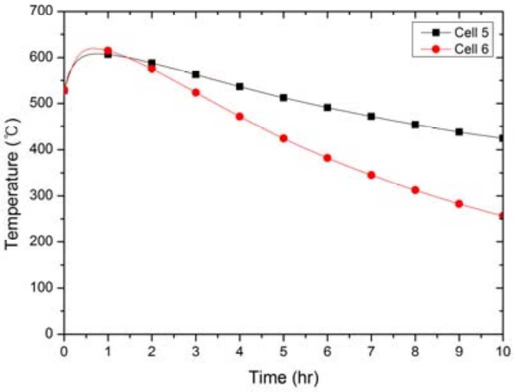

Fig. 4. Sodium Pool Temperature

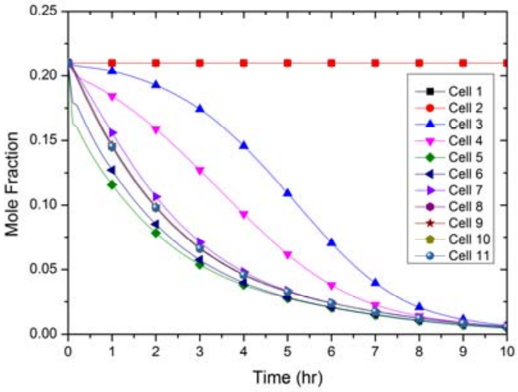

Fig. 5. Oxygen Mole Fraction

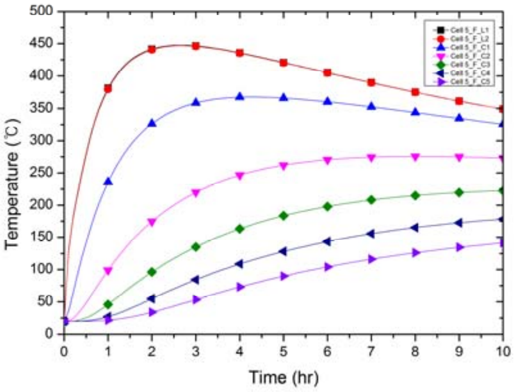

Fig. 6. Floor Temperature for Cell 5

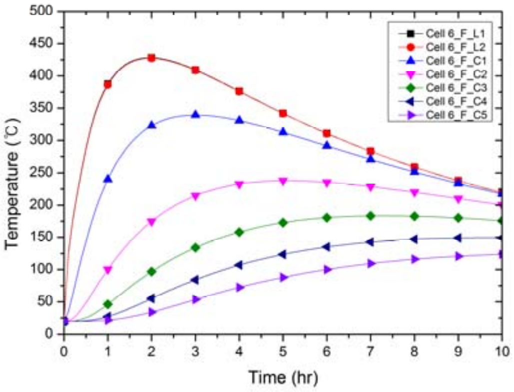

Fig. 7. Floor Temperature for Cell 6

3. Conclusions

For the sodium-induced fire in the annulus area of the containment, the preliminary containment responses are carried out using the CONTAIN-LMR computer code. The peak pressure and temperature of containment atmosphere rise up to 19 psia and 320 ℃ respectively and the peak temperature of concrete floor is increased to 370 ℃. This evaluation is preliminary results and the more sophisticated containment P/T model incorporating such as the detailed passive heat sink and occupied volume needs to be developed to determine containment design pressure and environmental qualification parameters in a future.

REFERENCES

[1] K. K. Murata, D. E. Carroll, K. E. Washington, F. Gelbard, G. D. Valdez, D. C. Williams, K. D. Bergeron, User's Manual for CONTAIN 1.1 : A Computer Code for Severe Nuclear Reactor Accident Containment Analysis, NUREG/CR-5026, 1989.

[2] K. K. Murata, D. E. Carroll, K. D. Bergeron, G. D. Valdez, CONTAIN LMR/1B-Mod. 1, A Computer Code for Containment Analysis of Accidents in Liquid-Metal-Cooled Nuclear Reactors, SAND 91-1490, 1993.