The Containment Performance Evaluation of the Sodium Fire Due to Leaks from DHRS in PGSFR

Sang-Jun Ahn[a*], Kwi-SeoK Ha, Hyung-Kook Joo
KAERI, 1045 Daedeokdaero, Yuseong, Daejeon, Republic of Korea 305-353
[*]*Corresponding author: enginasj@kaeri.re.kr*

1. Introduction

Korea Atomic Energy Research Institute(KAERI) has been developing the Prototype Generation IV Sodium Cooled Fast Reactor(PGSFR). It uses the sodium as a reactor coolant, which has the chemical characteristics to react with oxygen in the containment atmosphere. This interaction generates the sodium fire accompany by the various reaction products and high heat of reaction. It threaten the structural integrity of the containment building as a last radiological defense barrier interfacing with the outside atmosphere. The sodium of the decay heat removal system (DHRS) loop can be exposed to the oxygen in the containment atmosphere. Because the DHRS loop pipe from the reactor upper closure header goes through the outside containment. It is composed of the Passive Decay heat Removal Circuit (PDRC) and Active Decay heat Removal Circuit (ADRC). For the conservative evaluation of the event, the sodium within the PDRC loop is chosen by reason of the larger spilled sodium quantity.

In this paper, the sodium fire event due to the DHRS loop pipe leaks is evaluated inside the containment boundary. The thermal hydraulic influences generated by the sodium fire are calculated by CONTAIN-LMR [1] as a performance analysis code for the containment building in PGSFR.

2. Evaluation Methods

The development of the containment building design is in progress in PGSFR. The result of the evaluation is based on the offered design data [2] and limited only to the range inside of the containment boundary. It is applied the more conservative assumptions to evaluate the containment performance. This evaluation results will be considered to the determining the containment building design pressure.

2.1 Assumption & Calculation

The primary purpose to evaluate the integrity of the containment is that it has an important barrier to prevent the release of the radiological fission products to the outside containment. As a design basis event relating to the containment performance, it is chosen to the sodium fire event due to the DHRS loop pipe leaks. This event is occurred by contacting between spilled sodium with oxygen in the containment atmosphere. According to the degree of the spilled sodium pressure, the event is assorted into spray fire and pool fire. This event is categorized to the pool fire, because of the comparatively low pressure.

There are a few assumptions to be considered for conservative evaluation of the pool fire event. It is assumed that the spilled sodium is spread out on the floor of the containment. This is the reason to occur the result of the highest combustion rate of the sodium and consumption rate of the oxygen at early time. And, all of the spilled sodium participating on the reaction with oxygen is used to produce the sodium monoxide (Na_2O) which generates the much heat than the sodium peroxide (Na_2O_2). The event scenario is as follows. The sodium in the DHRS loop pipe is spilled out due to the pipe leaks. All the sodium is spread out on the floor of the containment. As soon as contacting the sodium with the oxygen of containment atmosphere, the sodium fire is occurred on the surface of the floor. As the fire is continuously preceded, the oxygen of the containment atmosphere is gradually depleted and the severity of the sodium fire is decreased.

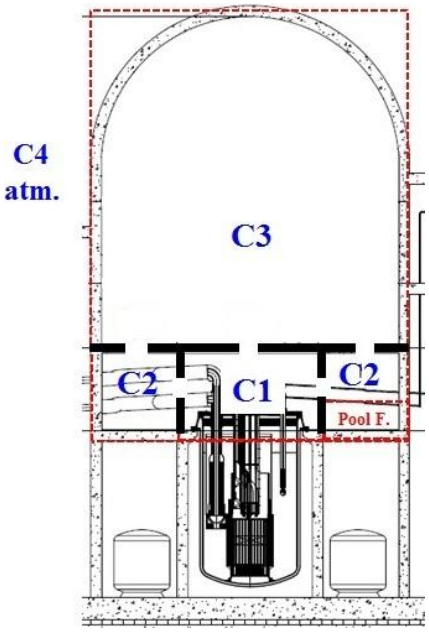

Fig. 1.CONTAIN-LMR Code Nodalization

Figure 1 shows the nodalization for the CONTAIN-LMR which is a performance analysis code relating to the containment in PGSFR. The containment domain to evaluate is composed of the 3 cells. In here, the cell 4

represents the atmosphere outside containment building. The leak rate to the outside containment conservatively assumed to a 1%/day of the containment volume at the containment design pressure. The sensitivity analysis of the flow path area between the cells is performed together. The flow path area is a 1.5 [m^2] and 3.0 [m^2]. The value between cell 2 and 3 is a 1.5 [m^2].

2.2 Calculation Results

Because the performance evaluation to the pool fire event is applied by the conservative assumptions, the combustion rate of the sodium and the consumption rate of the oxygen are dominantly generated at early time. For this reason, the pressure and temperature of the containment atmosphere represent the highest value at this time.

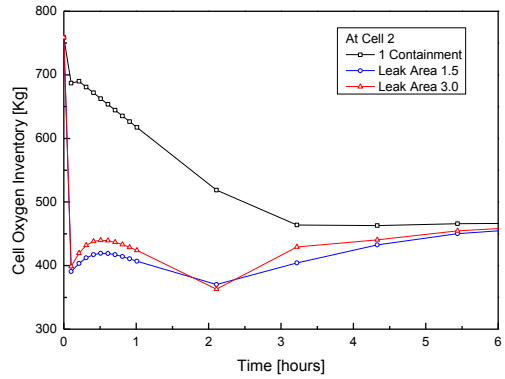

Fig. 2.Cell Oxygen Inventory with the lapse of time

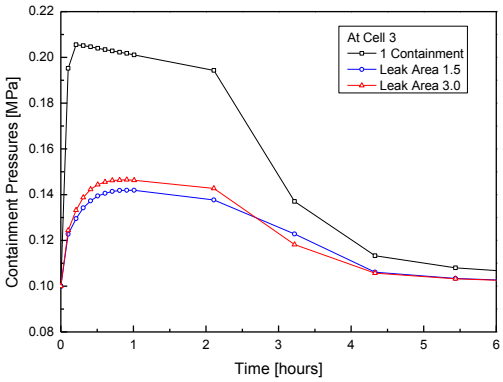

Fig. 3.Containment Pressures with the lapse of time

Figure 2 represents the result of the oxygen inventory variation with the lapse of time in the cell 3. The oxygen inventory to the cases of the two leak area variation is abruptly decreased at the early times, and then increase until the approximate initial 30 minutes. The increase of the oxygen inventory represents that the combustion reaction between sodium and oxygen is not properly occurred. The oxygen inventory of the 1 containment decreases gradually with the elapse of time. It represents the combustion heat to be generated continuously affect as a factor to increase the pressure and temperature of the containment atmosphere. Figure 3 represents the result of the containment pressure with the lapse of time. From the calculation result, it shows the case of the 1 containment has the highest pressure value. As above referred, it comes from decreasing the oxygen inventory gradually comparing with other two cases. The pressure value of the 3.0 leak area is higher than the value of the 1.5 leak area. It is the reason that the oxygen inventory in the cell 3 recovers more quickly comparing with the 1.5 leak area. This is due to the more large flow path area. As the oxygen in the containment is depleted, the pressure is gradually decreased as expected. The maximum pressure value shows below the approximate 0.207 [MPa].

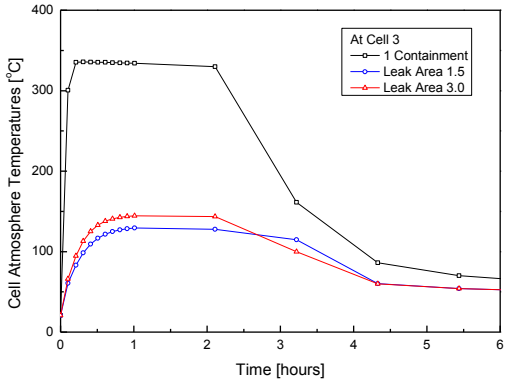

Fig. 4.Cell Atmosphere Temperature with the lapse of time

Fig. 4 represents the result of the cell atmosphere temperature with the lapse of time. It shows the case of the 1 containment has the highest temperature value. It is due to the variation of the oxygen inventory value at the early time. The maximum temperature is below the approximate 344.0 [^oC]. From the calculation result, the value of the temperature has a interrelate relation with the value of the pressure in the containment atmosphere.

3. Conclusions

The performance evaluation of the sodium fire event due to DHRS loop pipe leaks is calculated by using the CONTAIN-LMR code. From the results, the case of the 1 containment represents the most conservative result to the thermal hydraulic viewpoint. The maximum values of the pressure and temperature in the containment atmosphere are below of the 0.207 [MPa], 344.0 [^oC], respectively.

REFERENCES

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[2] In-Soo Han, Geometrical Design Data of the Containment Building, 2014.