Preliminary Performance Analysis of KALIMER Containment

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1. Introduction

KALIMER (Korea Advanced LIquid MEtal Reactor) 600 is a pool type advanced liquid metal reactor which is being developed in KAERI (Korea Atomic Energy Research Institute). To analyze the performance of preliminary design of KALIMER 600 containment, the thermal-hydraulic phenomena was investigated under sodium fire accident in containment and the exposure dose rates are estimated for the accident.

2. Containment design of KALIMER 600

The conceptual diagram of preliminary design containment of KALIMER 600 is shown in Figure 1. The containment structure is a 0.8m concrete building with 6mm steal liner and the floor outside of the sodium pool is concrete about 1m thick and steal liner. The basic design parameters are summarized in Table 1.

Table 1. Basic design parameters of KALIMER 600

Title	Parameter
Type and material	Concrete Building
Thickness	0.8 m
Liner material and thickness	6 mm
Dimension	24 × 21 × 10 m
Volume	5040 m^3

3. Containment Performance Analysis for KALIMER 600

3.1 Accident Scenario

The design basis accident for containment performance analysis is sodium pool fire. A relatively large breach in the reactor closure has been created by any reason, such as a HCDA. Then radioactive isotopes are instantly released to the containment volume.

In addition, it is assumed that the breach in the reactor closure is large enough to allow the He cover gas to escape into the containment dome and air is assumed to enter the reactor cover gas region, initiating a sodium pool fire, which continues until all the oxygen in the containment dome is consumed.

Burning of primary sodium within the reactor vessel results in the release of radioactive isotopes and sodium combustion products carry these isotopes into the containment dome atmosphere. It has been conservatively assumed that the complete core melts, and all the fission products are uniformly distributed in the primary sodium before burning initiates.

The accident source terms shown in Table 2, are based on study of KANG [3], where the source term is determined most conservatively.

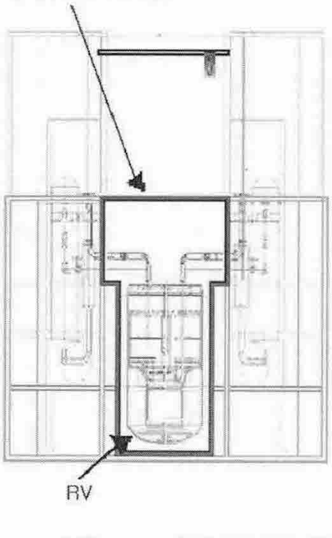


Figure 1. Conceptual diagram of KALIMER 600 containment

3.2 Containment Performance Analysis for KALIMER

With containment dome design, accident scenario and source terms described above, the containment thermal-hydraulic conditions, aerosol behavior and containment leak rate have been calculated with CONTAIN-LMR code [4], which is the LMR version of containment analysis code that can cope with severe accident condition.

The nodalization of KALIMER containment dome for CONTAIN-LMR analysis is shown in Fig. 2. The containment is divided into cells to allow establishment of convective air currents within the structure. Hot sodium is assumed to be in direct contact with the air in the containment atmosphere. A leak path is provided between the containment and the environment to allow release of material present in the containment atmosphere. Heat transfer between the containment atmosphere and these structures is considered. The environment outside of the containment dome is assumed to be at a nominal temperature of 311K(38℃) and heat is assumed to be passively removed from the containment dome by natural convection of air.

Figure 3a shows the pressure within the containment calculated by CONTAIN-LMR following the initiation of the sodium pool fire and introduction of the radioactive materials from the primary coolant. The peak of pressure is between 146.0 kPa. The pressure decreases to atmospheric pressure at about 10 hours following the pressure peak.

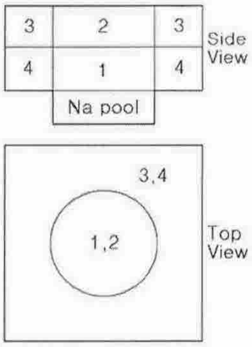


Figure 2. Containment Dome Nodalization for CONTAIN-LMR

The maximum temperature of containment atmosphere is 209.1℃ (Figure 3b). Figure 3c shows the containment oxygen mole fractions, which continually decreases due to the sodium pool fire. The containment oxygen is consumed about 320minutes. Depletion of the oxygen within the containment also contributes to the decreasing trend in the containment pressure. The sodium fire is terminated due to the lacks of oxygen and humidity at 400 minutes (Figure 3d).

3.3 Consequence Evaluation

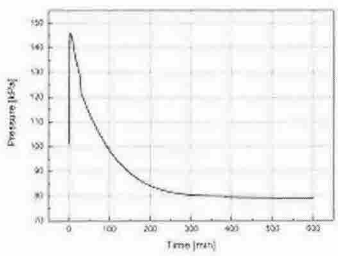
From the CONTAIN-LMR analysis results, the amount of each radionuclide leaked to environment can be obtained. The exposure dose rate at the plant site boundary has been estimated with MACCS code [5], which is environmental consequence calculation code, after processing the raw data into the form suitable to MACCS code. The relative dose is summarized in Table 2. It is apparent that the dose rate is very lower than the PAG and 10CFR100 limits.

Table 2. Exposure dose due to sodium fire

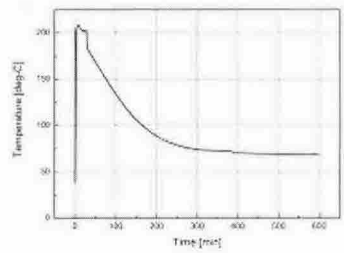
	KALIMER	PAG Limit	10CFR100
Whole body	0.0134	1.0	25
Red Marrow	0.0234	1.25	150
Lungs	0.0329	1.25	47
Thyroid	0.0451	5.0	300

4. Conclusion

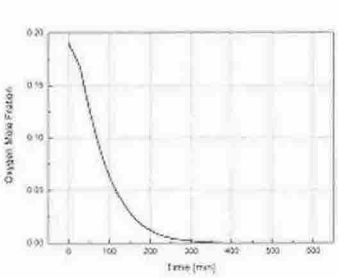
In this study, the preliminary design study on the KALIMER containment dome has been performed. Thermal-hydraulic condition under sodium fire accident is investigated and pressure and temperature profiles are calculated. It will affect further development of containment design and KALIMER containment vessel will has sufficient margin to accommodate work energy resulting from HCDA within it without reactor closure breach.



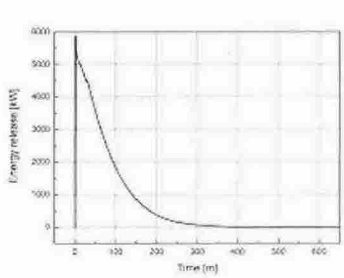
(a) Containment pressure



(b) Containment temperature



(c) Cell oxygen mass fraction



(d) Energy release rate

Figure 3. Thermal-hydraulic parameters in containment

Acknowledgements

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REFERENCES

[1] S. W. Lee, Y. M. Kwon, K. D. Kim, S. D. Suk, W. P. Chang and D. H. Hahn, Preliminary Design Study of the KALIMER Containment Dome, KAERI/TR-1240, Korea Atomic Energy Research Institute, 1999

[2] S. W. Lee, D. H. Hahn and S. D. Suk, Preliminary Design Study of the KALIMER Containment Dome, Proceeding of KNS autumn meeting, 1998

[3] C. S. Kang, J. H. Song, Y. H. Cho, H. S. Go, Y. W. Lee, and M. Jang, Development of Safety Analysis Technology of LMR – Development of Radioactive Source Terms in Liquid Metal Reactor, KAERI/CM-562, Korea Atomic Energy Research Institute, 2001

[4] K.K. Murata, *et al.*, "User's manual for contain 1.1, A Computer Code for Severe Nuclear Reactor Accident Containment Analysis", NUREG/CR-5026 SAND87-2309.

[5] D.I. Chanin, *et. al.*, "MELCOR Accident Consequence Code System (MACCS) User's Guide", NUREG/ CR-4691-Vol. 1 TI90 009797.