# Preliminary Performance Analysis of KALIMER-600 Containment Using CONTAIN-LMR with Frame Sheet Model

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## 1. Introduction

KALIMER-600 (Korea Advanced LIquid MEtal Reactor)00 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. Frame Sheet Model

The sodium pool fire model in CONTAIN-LMR [4] simulates the chemical reaction between sodium located in a pool and the oxygen in the atmosphere above pool. When the sodium burns, two reactions occur:

$$2\ Na + O_2 \longrightarrow Na_2O_2$$

$$4\ Na + O_2 \longrightarrow 2\ Na_2O$$

The first (peroxide) reaction produces 10.97 MJ/kg of sodium and the second (monoxide) reaction produces 9.05 MJ/kg of sodium. The reaction energy and reaction products are contributed to pool and atmosphere. But, this contribution ratio defends on user's decision and has no physical base.

For the more accurate and physically agreeable analysis on the energy distribution, frame sheet model is introduced to the CONTAIN-LMR code. Frame sheet model calculates the energy and mass balance in the frame sheet and contribution of reaction products to pool and atmosphere.

## 3. Containment Performance Analysis for KALIMER-600

### *3.1 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 0.5m 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.

### *3.2 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.

### *3.3 Containment Performance Analysis for KALIMER*

With containment dome design, accident scenario and source terms described above, the containment thermal-hydraulic conditions, aerosol behavior and

Table 1. Basic design parameters of KALIMER 600

| Title | Parameter |
|---:|---|
| Type and material | Concrete Building |
| Thickness | 0.5 m |
| Liner material and thickness | Steel, 6 mm |
| Dimension | 22 × 22 × 31 m |
| Volume | 15,000 $m^3$ |

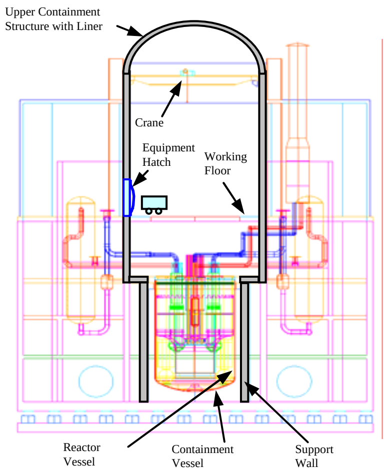



Figure 1. Conceptual diagram of KALIMER-600 containment

containment leak rate have been calculated with CONTAIN-LMR code, 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 140.5 kPa, which is lower than the value predicted by diffusion model. The pressure decreases slowly to 138.9 kPa after 72 housrs.

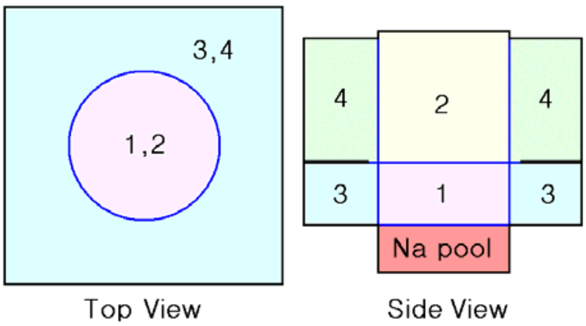
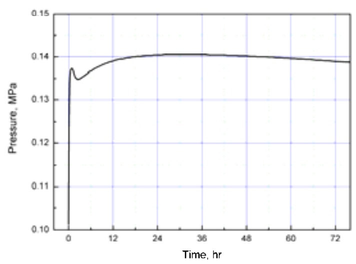
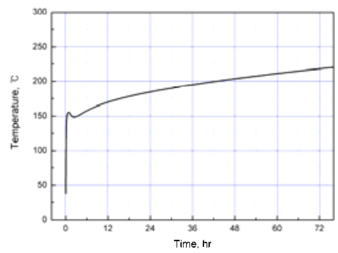


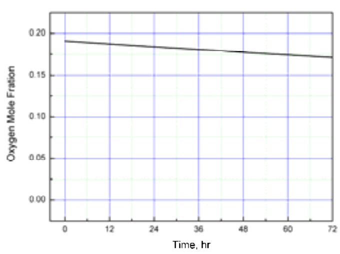

Figure 2. Containment Nodalization for CONTAIN-LMR



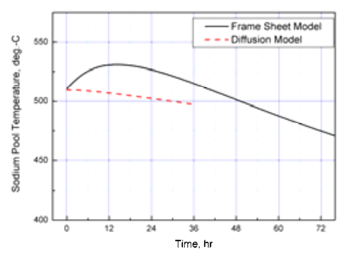

(a) Containment pressure




(b) Containment temperature




(c) Cell oxygen mass fraction




(d) Energy release rate

Figure 3. Thermal-hydraulic parameters in containment

At 72 hour. the temperature of containment atmosphere becomes 218.5 ℃ and increases at the rate of 0.55 ℃/hr (Figure 3b). Figure 3c shows the containment oxygen mole fractions, which continually decreases due to the sodium pool fire. Figure 3d shows the temperature of the sodium pool, which is compared with that of diffusion model. In old calculation by diffusion model, all energy and reaction products enter atmosphere, which increases pressure and temperature of atmosphere and enhance sodium burning. For the frame sheet model which calculates the distribution ratio, some part of reaction products enters pool and the temperature of sodium pool is higher than that of diffusion model.

## 4. Conclusion

In this study, the preliminary design study on the KALIMER containment 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 sodium pool fire within it without reactor closure breach.

## Acknowledgements

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