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# Preliminary Study of Applying Phase Change Materials (PCM) for Containment Passive Cooling

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## 1. Introduction

The containment building is primarily designed to prevent or mitigate the uncontrolled release of radioactive material to the environment. Therefore it is considered to be the fourth and final barrier in the defense in depth strategy. In case of Design Basis Accidents (DBA), the pressure increases significantly and containment safety system should maintain the integrity of the containment by suppressing the pressure and temperature of the containment atmosphere below the design limits.

Most of Pressurized Water Reactor (PWR) containments use fan cooler systems and containment spray systems. However, the importance of passive safety system has increased after the Fukushima accident. As the main passive safety system, Passive Containment Cooling System (PCCS), which utilizes natural phenomena to remove the heat released from the reactor, is suggested in the advanced pressurized water reactor (APWR). To increase the efficiency of passive cooling, additional passive containment cooling method using Phase Change Material (PCM) is suggested in this paper.

PCM has a good potential because it stores heat energy as a form of latent heat during phase change. They are commercially used to capture solar energy and to maintain temperature to the desired temperature in buildings. For containment using PCMs, there are many advantages. First, there is little need for maintenance cost during operation because it is changed only at desired temperature (accident conditions). Therefore replacement or refilling is not needed during normal operation. Second, application to operating power plant is possible without new design of containment because it doesn't require special structures or penetration through the containment. It can be used with other containment safety systems such as the PCCS to increase efficiency of cooling. In building applications, PCM is encapsulated in concreate and gypsum to prevent leakage of liquid state material during phase change and to be reused for a long time. However these methods decrease efficiency of cooling. So, a new model without encapsulement of PCM is necessary

After the material is selected and the design work with better heat transfer is performed, pressure and temperature trends and hydrogen concentration can be calculated. In this paper, the results from the preliminary study is presented. The calculation of the containment parameters were performed with the CAP code, which was developed by a consortium of Korean nuclear industries for the thermal hydraulic analysis of nuclear power plant containment.

## 2. Methods and Results

### *2.1 PCM*

Based on the thermophysical properties of commercially available PCMs, the material can be selected. The selection criteria are listed in Table I.

Table I: Criteria for PCM to apply to the containment

| | Criteria | Remark |
|---|---|---|
| 1 | Organic material | Organic material is less corrosive than inorganic material and has chemical and thermal stability |
| 2 | Melting near 50~70℃ (accident condition) | PCM should be melted near 50~70℃ to cooling containment in accident |

By screening the list of substances with the suggested criteria, the final list of suitable candidate materials conditions are proposed in Table II.

Table Ⅱ: Thermophysical properties of commercially available PCMs near the desired temperature.

| | Material | Type | Melting temperature (℃) | Latent heat of fusion (kJ/kg) | Thermal conductivity (W/m•K) | Specific heat (kJ/kg•K) |
|---|---|---|---|---|---|---|
| 1 | PureTemp68 | Organic | 68 | 198 | n.a. | 1.85 |
| 2 | PureTemp63 | Organic | 63 | 199 | n.a. | 1.99 |
| 3 | A62 | Organic | 62 | 145 | 0.22 | 2.2 |
| 4 | PureTemp60 | Organic | 61 | 230 | n.a. | 2.04 |
| 5 | A60H | Organic | 60 | 145 | 0.22 | 2.22 |
| 6 | RT60 | Organic | 60 | 144 | n.a. | n.a. |
| 7 | A58H | Organic | 58 | 243 | 0.18 | 2.15 |
| 8 | PureTemp58 | Organic | 58 | 237 | n.a. | 2.47 |
| 9 | A58 | Organic | 58 | 132 | 0.22 | 2.22 |
| 10 | RT58 | Organic | 58 | 160 | n.a. | n.a. |

n.a.: not available.

### *2.2 Sensitivity Study*

A sensitivity study was conducted to identify the effect of heat conductor location to the containment pressure and temperature history.

The sensitivity analyses of the containment pressure and temperature with respect to the location of installed

PCM are performed for the Double Ended Discharge Leg Slot Break (DEDLSB) of Shin-Kori Units 3&4 using CAP code. The mass and energy release data are taken from the result of SPACE. Heat Conductor Description is listed in Table III. The results from the analysis are presented in Figs. 1-4.

From Fig 1, most cases showed slightly higher pressure than the initial case. However the wall 6, 9 cases showed lower pressure than the initial case.

Table III: Heat Conductor Description

| Heat Conductor | Structure |
|---|---|
| Wall1 | Containment cylinder |
| Wall2 | Dome |
| Wall3 | Basement |
| Wall4 | Embedment concrete |
| Wall5 | Unembedment concrete |
| Wall6 | Lined fuel pool |
| Wall7 | Inside of IRWST |
| Wall8 | Polar crane and Bridge |
| Wall9 | SIT |

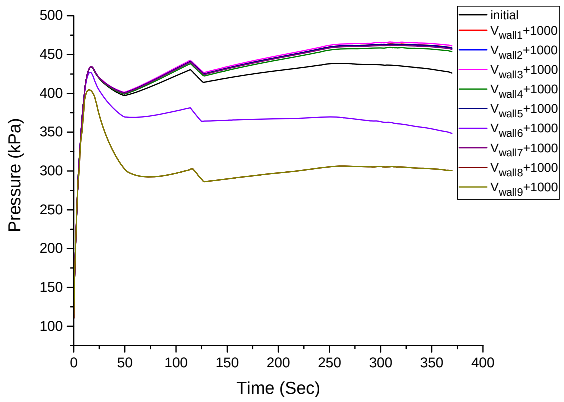


Fig 1. Effect of the Heat Conductor Size on Containment Pressure

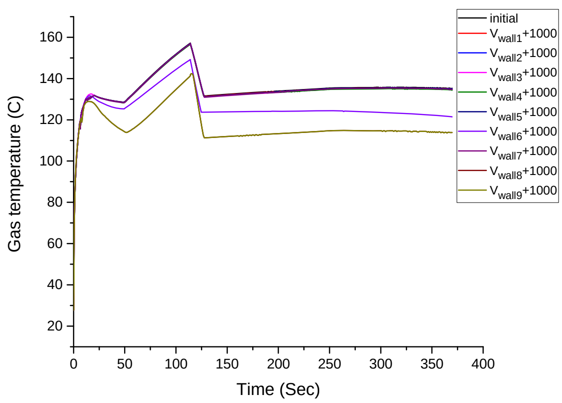


Fig 2. Effect of the Heat Conductor Size on Containment Steam Temperature

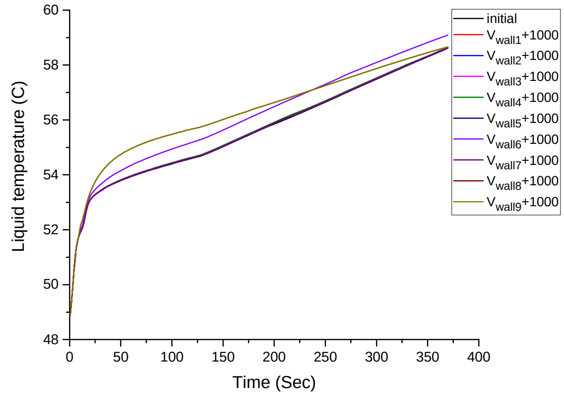


Fig 3. Effect of the Heat Conductor Size on Containment Water Temperature

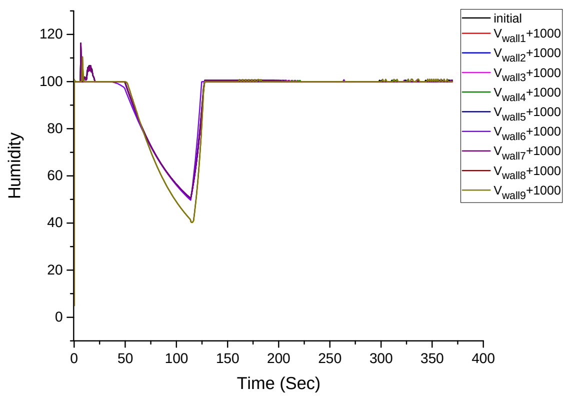


Fig 4. Effect of the Heat Conductor Size on Containment Humidity

From Figs. 2~4, most cases showed almost the same results as the initial cases. However the wall 6, 9 cases showed lower steam temperature, higher water temperature and higher humidity than the initial case.

## 3. Summary and Further works

Phase Change Material (PCM) is proposed as an additional passive containment cooling method to increase the efficiency of passive cooling in this paper. To apply proper PCMs to containment, commercially available PCMs were screened while reviewing thermophysical properties data and suggested selection criteria.

A sensitivity study was also carried out to identify the effect of potential installation location of PCM using the CAP code. The pressure of containment in most cases showed slightly higher than that of the initial case. For the temperature of steam and water and humidity, similar results with the initial case were showed in most cases.

As the next step, further sensitivity study will be conducted and the installation location of PCM will be decided. Then, the pressure and temperature of containment in LBLOCA will be calculated to evaluate the performance of the passive cooling containment with PCM.

## ACKNOWLEDGEMENT

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