Conceptual Design of K-DEMO Containment

Kyemin Oh[a], Gyunyoung Heo[a*], Young-seok Lee[b], Hyoung-chan Kim[b], Young Tae Moon[c]
[a]*Kyung Hee University, Yongin-si, Gyeonggi-do, 446-701, Korea*
[b]*National Fusion Research Institute, Daejeon-si, 305-333, Korea*
[c]*KEPCO Engineering & Construction Company, inc., Yongin-si, Gyeonggi-do, 446-713, Korea*
[*]*Corresponding author: gheo@khu.ac.kr*

1. Introduction

The most important safety goal of nuclear systems is to prevent the release of radiation into the environment, and fusion power plants should not be an exception. Containment is the final wall to avoid leaking radioactive materials in malfunction of vacuum vessel and fuel cycle failure. It is important barrier to protect the plant against external events such as aircraft crashing, earthquake, and tsunami.

After the Fukushima accident in Japan, the passive safety systems are being researched due to their high reliability, simple computation systems and small number of components. However, it is hard to say well because of negative points, which are low efficiency and uncontrollability. So, it is necessary to confirm its performance & suitability using simulation and experiments.

Passive safety systems work on the basis of differential head, natural convection and gas compression force without operator and a power supply. Currently, safety systems using the passive power are applied in APR-1400 and next generation of power plants in domestic. However, it's hard to verify the performance of passive safety systems.

Though code calculation and numerical analysis are suitable to certain extent for the system(s) with differential head and gas compressive force but these methods are difficult to apply for analysis of natural convection systems. These safety systems are mainly used in containment cooling systems. It is most plausible that such kind of containment cooling system will sustain its design in the next generation nuclear power plants. The application of this safety system requires internal authentication whereas there is not sufficient experimentation or codes for authentication.

This paper is written under one program of Nuclear Fusion Research Institute (NRFI). Henceforth, the performance analysis method is being developed for the analysis of Passive Containment Cooling System (PCCS) using the basic accident analysis code for the fission plant. The analysis methods for natural convection and condensation phenomenon are suggested by 3-dimentional analysis using the GOTHIC code that is developed for calculation of temperature/pressure for containment of nuclear power plant.

2. Methods and Results

2.1Passive Safety System

According to the driving mechanism, safety systems are divided into passive and active systems. The representative safety systems of power plants currently operating in Korea require external driving sources. However, the studies related to passive systems are actively taking place domestically and internationally because of specific characteristic of passive systems that is working irrespective of the power supply in the event of an accident. It is worthwhile to make an attention for passive systems particularly after Fukushima accident.

Table 1 shows a comparison between various aspects of passive and active safety systems.

Table.1 The feature of active/passive systems

Active System	Passive System
High efficiency Well defined performance easy & fine controllability	Highly reliable Simple configuration Small number of components
Requiring external power Complicated configuration Huge components	Low efficiency Hard to prove its performance Hard to control Potential unknown phenomena

2.2 Passive Containment Cooling System

Most of safety systems work on the principles of differential pressure head, gas compressive force or natural convection. So most of containment cooling systems are being developed base on natural circulation. This is also suitable for fusion reactor. Diverse containment cooling methods are being suggested using natural convection between containment wall & external air and containment internal/external heat exchanger. In this paper we carried out performance analysis of PCCS, as shown in Fig.1.

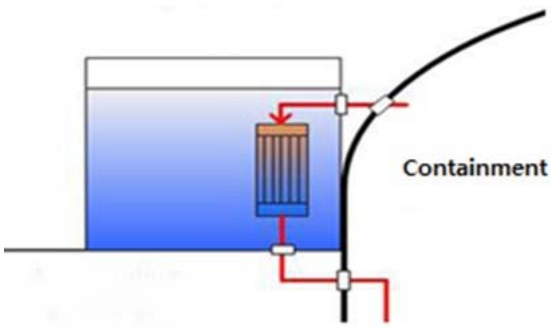

Fig.1 Schematic Diagram for PCCS

2.3 GOTHIC code

The code to model safety system is GOTHIC ver. 7.2b. This code is designed to assess the performance of components related to safety against large break LOCA, temperature/pressure of containment.

GOTHIC solves the conservation equations for mass, momentum and energy for multi-component, multi-phase flow in lumped parameter and/or multi-dimensional geometries. The phase balance equations are coupled by mechanistic models for interface mass, energy and momentum transfer that cover the entire flow regime from bubbly flow to film/drop flow, as well as single phase flows. The interface models allow for the possibility of thermal non equilibrium between phases and unequal phase velocities, including countercurrent flow. GOTHIC code is convenient to model control volume, thermal conductors and flow paths in the 1-D as well as 3-D analysis. Component modeling like pump, valve, heat exchanger etc. can also be modeled easily with their forcing functions and control variables [1].

2.4 Analysis of Cooling Performance of PCCS

This section describes the performance analysis for PCCS against LOCA. We assumed 8" break and referred design parameter of Korea standard nuclear power plant and ITER [2].

2.4.1. PCCS modeling using GOTHIC code

Steam coming in outside water tank through upper tube is condensed into water and is discharged through lower tube inside the containment. This process of steam inflow and water outflow continues due to the difference in density of water and steam. Difference of height of tubes is modeled, as shown in Fig.2. Heat conductors are modeled to describe heat transfer between tubes and water tank. Heat transfer coefficient used in GOTHIC code is Uchida correlation that is applied to describe natural convection.

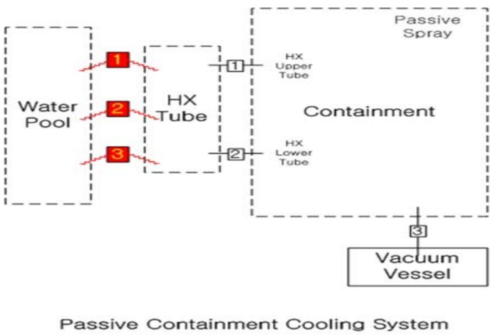

Fig.2 Passive containment cooling system model (GOTHIC)

2.4.1. Results of Cooling Performance

Fig.3 and 4 shows flow rate of upper/lower tube. In this result, steam coming in upper tube is condensed and discharged in the form of water. It can be concluded that containment cooling continues persistently, provided the amount of water in outside tank is sufficient.

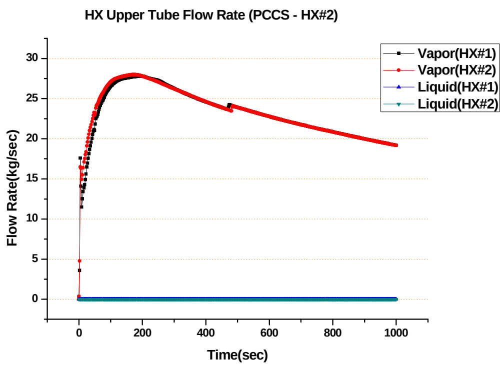

Fig.3 Upper tube flow rate of passive heat exchanger

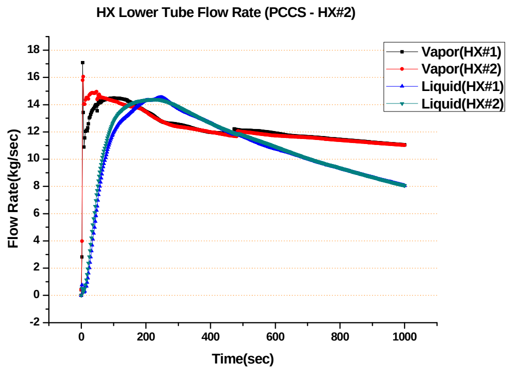

Fig.4 Lower tube flow rate of passive heat exchanger

3. Conclusions

This paper summarized passive safety systems developed internally and externally and carried out the performance analysis of PCCS using basic accident analysis code. We successfully modeled condensation and natural circulation using GOTHIC code and established the characteristics of passive system. However, quantitative data is not sufficient to prove the performance of passive safety system. Also, GOTHIC code has not been designed specifically for natural circulation. Thus, it is suggested that further analysis should be performed for the verification of this system.

ACKNOWLEDGEMENT

This work as supported by R&D Program through the National Fusion Research Institute of Korea (NFRI) funded by the Government funds.

REFERENCES

[1] George, T.L. et al, GOTHIC Containment Analysis Package User Manual Version 7.2b, NAI 8901-02 Rev 18, Numerical applications, Inc., Washington, USA, March, 2009

[2] Kang, M., Cho, J., Ahmed, R., Heo, G., Kim, H.J., Lee, Y., Design Failure Mode and Effect Analysis for Korean Fusion DEMO Plant, Fusion Engineering and Design , Portland, USA, September, 2011