Conceptional design about the Passive Containment Cooling System using Multi-pod Heat Pipe

Seung-Won Han, Sang-Nyung Kim*
Kyung-Hee University, 1, Seocheon-dong, Giheung-gu, Yongin-si, Gyeonggi-do
*Corresponding author: snkim@khu.ac.kr

1. Introduction

The Emergency Containment Spray Backup System (ECSBS) is scheduled to be introduced for the new Gori NPP Units 3 & 4 (APR-1400). This system is designed to assist the spray function of the nuclear reactor building during a serious accident greater than the design basis accident. It is a major accident relief system that is activated in case the overpressure-preventing device of the nuclear reactor building fails to function properly during a major accident relief system [1].

As far as ECSBS is concerned, however, it is very difficult to satisfy relevant conditions, such as performance requirements, penetration requirements and reliability requirements, and fire trucks must be waiting all the time, the water supply conditions must be met, and maintenance of the filtering system costs too much, many difficulties are expected. Accordingly, this study completed the conceptual design of a Multi-Pod Heat Pipe (MHP) that minimizes the penetration of the containment vessel, satisfies performance requirements like cooling performance, and is easy to maintain and economical.

2. Design concepts of MHP

The MHP for emergency cooling of the containment building consists of the condensation region, the adiabatic region and boiling region as a general Heat Pipe does (Fig. 1.). As it must be installed inside the nuclear reactor containment building, to minimize the penetration pipe, the insulator was designed as a single cylinder, and in such a way as to be structurally solid.

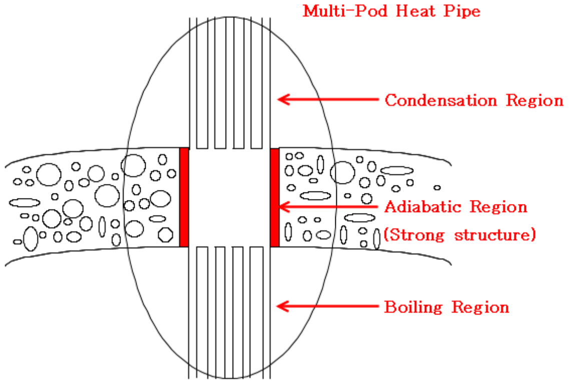

Fig. 1. Conceptional design of MHP

2.1 Design of Boiling Region

For the boiling region a number of Heat Pipes are tied in the form of a Hexagonal array to make Heat Pipe arrays, and these arrays are combined again to make one MHP assembly. Each array is connected to the adiabatic region, and the gas comes into the boiling region, and the gas condensed in the condensation region goes through the adiabatic region and flows into the boiling region in natural circulation. Also, as the pipes are connected to each other with fins, they serve as supports and heat sinks. The edges of the arrays are surrounded by external walls to protect the arrays and improve heat transfer by the chimney effect.

2.2 Design of Adiabatic Region

The adiabatic region sends the vapor generated by the boiling region to the condensation region, and serves as a channel that sends the liquid fluid condensed in the condensation region back to the boiling region. Also, the adiabatic region must be attached to the containment building air-tightly, and strong enough to withstand the physical weight within a certain range. Lastly, it must be designed so that it can be easily replaced.

2.3 Design of Condensation Region

The thermal design is irrelevant to the adiabatic region and the boiling region, or does not matter much. As the condensation region transfers heat to the air through natural convection, however, it has a very low heat transfer coefficient. Accordingly, to hold back the tremendous decay heat from the containment vessel, a great deal of heat transfer area and a way of improving heat transfer are needed.

- Lengthening of the Heat Pipe: It is desirable to increase the length of the Heat Pipe to about 5m.
- Fin attachment: Pipes can be connected to one another by fins with good thermal conductivity to improve heat transfer, maintain the space between fins and use them as supporting grids.
- Arrangement: As the condenser increases the accumulation of Heat Pipes, a hexagonal array is adopted to minimize the space occupied by the Heat Pipe assembly.
- Chimney installation: A chimney is installed not only to protect pipes, but also to improve convective heat transfer due to the chimney effect.
- Optimal D/P: If D/P is about 2.0, the heat transfer rate can be tripled.

2.4 Shape of Adiabatic Region

The adiabatic region has a double-cylindrical structure. The outer cylinder is structurally solid and protruding fins are installed around it so that it can be easily installed in the containment building or easily detached during repairs. At this time, support fins are installed on the outside of the adiabatic region, and L-shaped grooves are installed on the structure of the containment building and turned along with the screws, and the gaps are sealed with sealants. It is easily installed and detached and can prevent the dislocation of the MHP due to the internal pressure of the containment vessel (Fig. 2.).

The internal cylinder has a double structure. The liquid condensed in the condenser flows down and the external circular space serves as a channel through which the liquid gasified in the boiling region flows up to the condensation region so that the thermo-hydraulic phenomenon (CCFL or entrainment) due to the counter-current flow between the liquid and the gas, which is harmful to the performance of the heat pipe, can be prevented.

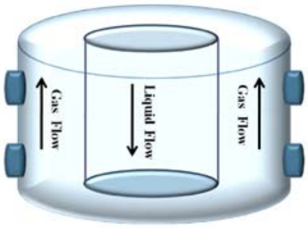

Fig. 2. Conceptional design of Adiabatic Region

The final configuration and arrangement of the MHP are illustrated in Fig. 3 and 4.

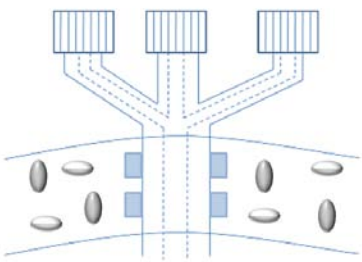

Fig. 3. Plane Diagram of MHP (Outside of Containment)

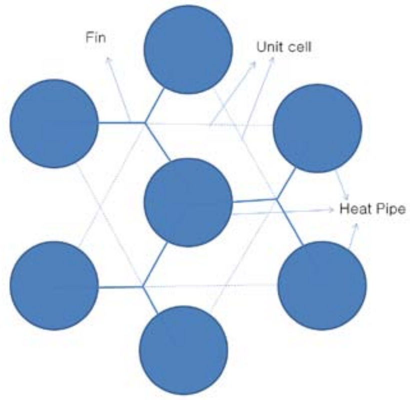

Fig. 4. Vertical Diagram of MHP (Outside of containment)

3. Conclusions

This study established the theoretically proper conceptual design of the MHP. In particular, by establishing the basic concept of the condensation region and the adiabatic region, which are the most important to MHP design, this study satisfied the theoretical performance requirements, penetration requirements and reliability requirements of the containment building. In addition, it presented a way to improve heat transfer, and made it easy to install and detach the adiabatic region so that maintenance and operations can be done more economically. If an optimal system is configured through simulation and verification experiment in the future on the basis of this conceptioal design of MHP, it will have greater utility as a realistic application technology.

ACKNOWLEDGEMENT

This work was supported by the Nuclear technology Undergraduate Student Society program of National Research Foundation of Korea (NRF).

This work is the outcome of a Manpower Development Program for Energy & Resources supported by the Ministry of Knowledge and Economy (MKE).

REFERENCES

[1] KHNP, A Review Report on the Applicability of ECSBS to New Gori NPP Units 3 and 4, 2006
[2] Sang-Nyung Kim, The Passive Cooling Structure of the Containment Vessel Using the Multi-Pod Heat Pipe, 2009