Concept of Hybrid Residual Heat Removal System through using Air and Sea water for Ship SMR(Small and Medium sized Reactor)

Kang Kyung Jun [a], Yong Hwan Yoo [a], Kim Soo Hyoung [a]*
[a] Korea Atomic Energy Research Institute, 989-111 Daedoek-daero, Yuseong-gu, Daejeon, 305-353
[*]Corresponding author: kkj@kaeri.re.krk

1. Introduction

SMRs(Small and Medium sized Reactor) applied to ships produce electricity through nuclear reactors and are used for propulsion. The residual heat removal system is a system for eliminating residual heat generated from the reactor upon accident, and the existing PRHRS(Passive Residual Heat Removal System) removes the heat through water cooling through ECT(Emergency Cooling Tank).[1] However, large upper water tanks, such as ECT, may make a safety risk by causing problems with the ship resilience to be applied to ships. This study is intended to propose PRHRS of ship SMRs to prevent these problems through using air cooling and sea water. The hybrid method of upper air cooling stack and lower seawater cooling is not only to make the most of the external heat sink for long-term cooling in the nuclear propulsion SMR, but also to maintain the circulation flow rate caused by hydraulic head of the condensation water through the upper air cooling.

2. System description

Figure 1 shows the schematic of the hybrid residual heat removal system for ship SMR. The design requirements for heat removal system of SMR are as follows. -The temperature of the RCS(Reactor Cooling System) shall be lower than that of safe shutdown condition at 36 hours after an accident occurrence and maintain this state until long-term. – The cooling rate of the RCS shall not exceed the maximum 40℃/hr for the integrity of the internal structure of the reactor.

The residual heat removal system consists of four independent trains and each train is composed of chimney for air cooling including condensation heat exchanger (PHx#1) and heat exchanger by sea water (PHx#2). The inlet of PHx#1(air cooling) is connected to a set of three steam generators (SGs). In the event of an accident, the steam generated from the steam generator by residual heat produced from the core flows to PHX#1. The steam condenses inside the condensation heat exchanger included in the air cooling chimney. Due to the density difference between the air inside and outside the chimney, the outside air is sucked the chimney. The PHx#2 is a heat exchanger for removing residual heat using seawater. The condensation water through upper air-cooled chimney enters the seawater heat exchanger. In the PHx#2, subcooled water is cooled by natural convection of external seawater. The cooled water passes through the containment boundary and circulates to the feed water line of the steam generator inside reactor. The difference between PHx#1 and the steam generator determines the flow rate in the system and is related to the size of the air and seawater cooling heat exchanger.

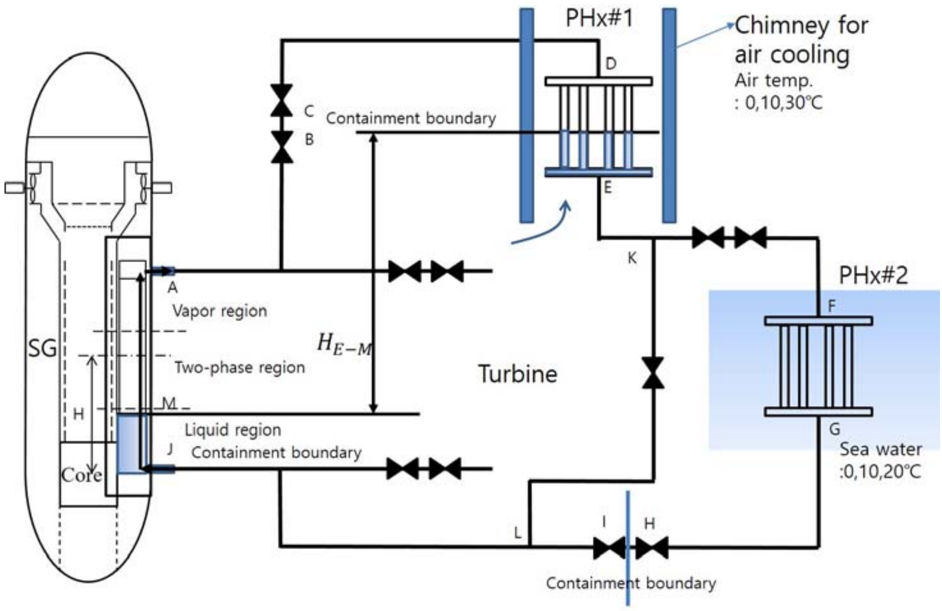

Fig1. Schematic of hybrid residual heat removal system by air and sea water

3. Concept design for heat exchanger through usign air and sea water

The PHx#1 and #2 remove the residual heat generated from the reactor by air and seawater respectively. The PHx#1 is installed perpendicular to the upper deck of the ship as shown in Figure2. It consists of the chimney duct and condensation heat exchanger located in the duct. The outside air is sucked from the intake part of the bottom of the condensation heat exchanger. The shape of the condensation heat exchanger is the honey comb type in which the external cooling air penetrates through the inside tube, and the natural convection can be smooth. The steam from steam generator flows outside the tube and condenses through heat exchanger with the cooling air, and condensation water drops downwards. The subcooled liquid is collected at the outlet of the heat exchanger and flows into the PHx#2. Figure 3 shows the concept design of the heat exchanger attached to the bottom of the ship and submerged in seawater. From PHx#2, the condensation water entered into the inlet of the heat exchanger flows through the inside of the tube, and external seawater flows in through the lower opening, and then flows out through the upper opening after heat exchange.

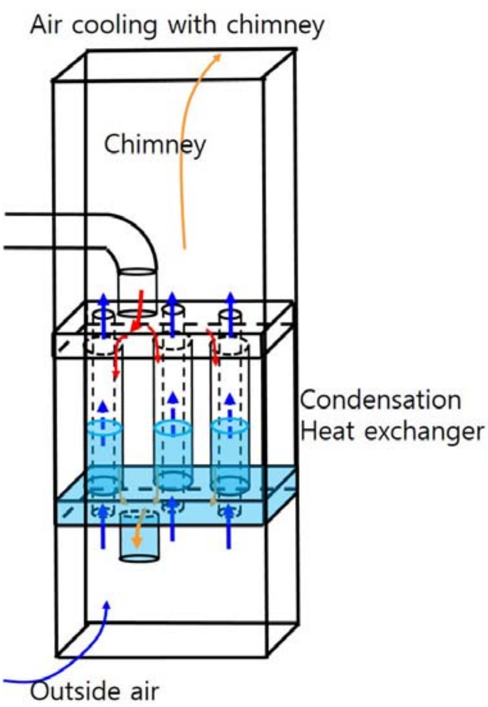

Fig 2. Air cooling system with condensation heat exchanger

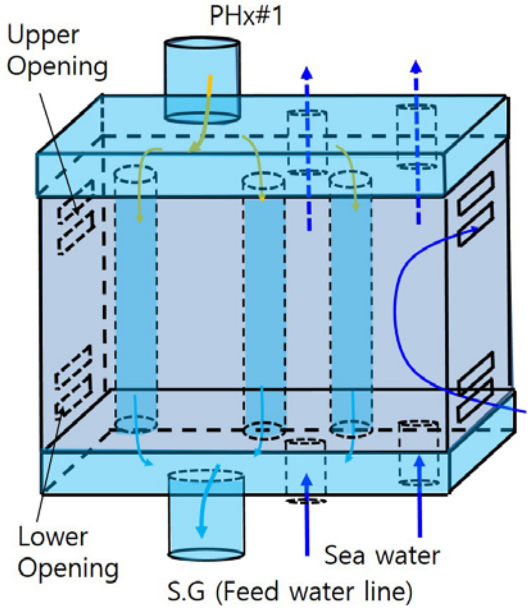

Fig 3. Heat exchanger configuration by sea water

4. Conclusions

In this study, the concept design for hybrid residual heat removal system was proposed to eliminate the residual heat generated from the ship SMR. The existing land SMRs eliminate residual heat from reactor by using large water tank such as ECTs, but excluded upper ECTs for ship use and developed air-cooled chimney and seawater heat exchanger. Detailed air cooling chimney and seawater heat exchanger size and performance analysis will be performed.

ACKNOWLEDGE

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REFERENCES

[1] Park et al. Experiments on Component Effect for Performance of SMART PRHRS using the high temperature/high pressure thermal-hydraulic test facility, KAERI/TR-3023/2005