Preliminary Thermal Sizing of PRHRS Heat Exchanger for Innovative Next Generation SMART Plus

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INTRODUCTION

Recently, the Korea Atomic Energy Research Institute (KAERI) and the King Abdullah City for Atomic and Renewable Energy (K.A.CARE) had established a Joint R&D Center to conduct a joint project. The main goal of this project is to propose a preliminary design of innovative next generation SMART (System-integrated Modular Advanced ReacTor) Plus to enhance its economic efficiency and safety by uprating reactor power and by introducing innovative element technologies, such as printed circuit steam generator (PCSG), internal control rod drive mechanism (CRDM), an improved reactor vessel module, and so on. In the project, a preliminary design of passive residual heat removal system (PRHRS) will be performed. In the present study, the heat transfer area of PRHRS heat exchanger (PHX) for SMART Plus will be estimated.

DESCRIPTION OF PRHRS HEAT EXCHANGER

The PRHRS consists of four independent trains and each train is composed of one emergency cooldown tank (ECT), one PHX and one PRHRS makeup tank (PMT).

The PHX consists of inlet header, vertical once-through type heat transfer tube, and outlet header, and performs the function to remove the residual heat of the core and the sensible heat in the reactor coolant system (RCS) through the cooling water in the ECT. The PHX locates inside of the ECT, and the RCS is cooled down as the coolant circulates naturally through the inside of the heat transfer tube of the PHX. The heat removal capacity of the PHX is calculated such that the RCS reaches the safe shutdown condition within 36 hours after an accident initiation.

In the calculation of the heat removal capacity of the PHX, the heat transfer degradation effects by non-condensable gases are considered. The heat transfer tubes of the PHX are submerged in the ECT cooling water.

DESIGN REQUIREMENTS OF THE PRHRS

The performance of the PRHRS shall meet the following requirements:

A. The temperature of the RCS shall be lowered below that of the safe shutdown condition within 36 hours after the accident initiation and the PRHRS shall maintain this condition until at least 72 hours without an operator's intervention or an emergency AC power.

B. The cooling rate of the RCS shall not exceed the design limitations of the RCS and connecting equipment.

The heat transfer area of the PHX shall be determined to meet the above requirements satisfactorily.

THERMAL SIZING OF PRHRS HEAT EXCHANGER

In this paper, the homogeneous flow model [1] is adopted. It considers the two phases to flow as a single phase possessing mean fluid properties. It is assumed that the two-phase flow discharged from the outlet of the SG is maintained along the vertical and horizontal steam line until it reaches the inlet of the PHX. Even though this assumption does not reflect a real phenomenon precisely, it is practical for the preliminary design since the homogeneous flow model is faster and converged relatively well. Calculation procedures are identical to the previous ones for SMART [2].

The heat transfer area shall be determined to meet the design requirements of the PRHRS. The heat transfer area is dependent upon diameter, length and the number of heat transfer tubes. Therefore, a parametric study is conducted with the various number of tubes, while diameter and length are fixed as same as previous values of SMART [2].

RESULTS

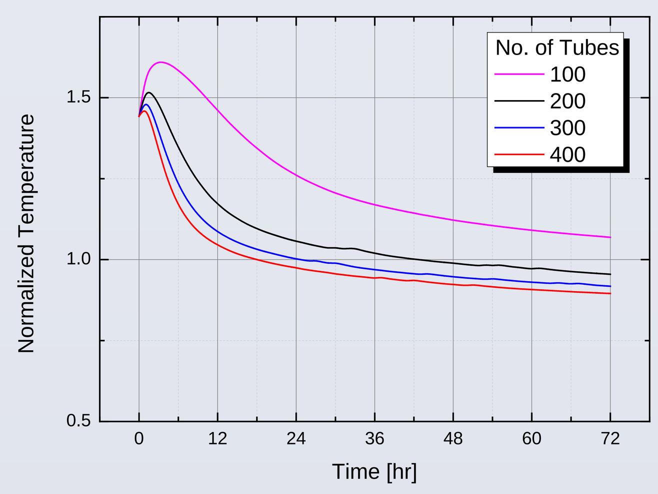

Fig. 1. Normalized RCS temperature (3 Trains)

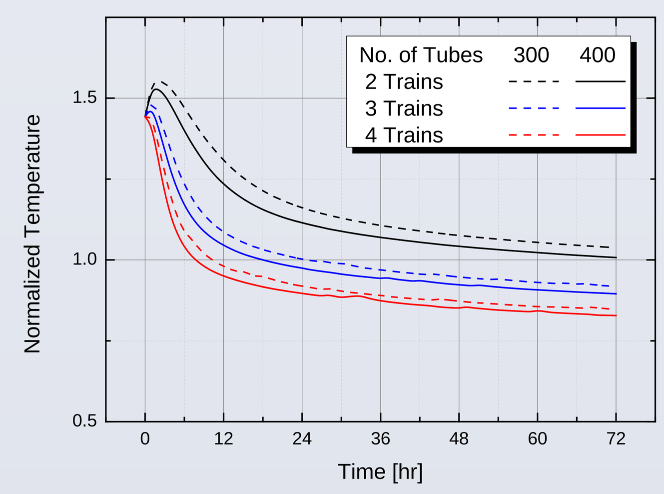

Fig. 3. Normalized RCS temperature (300/400 Tubes)

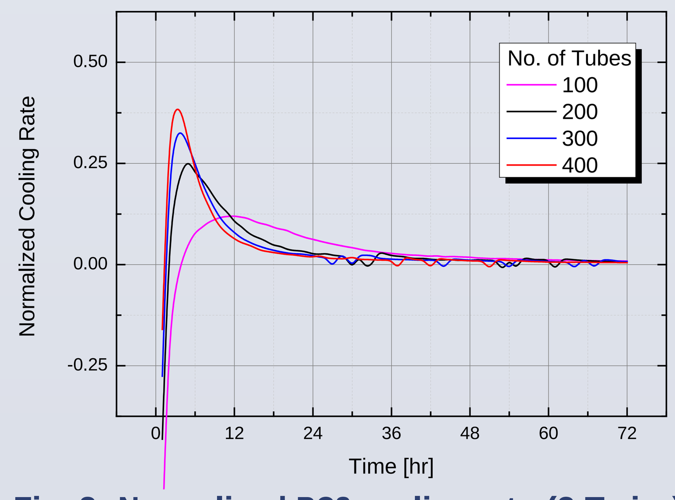

Fig. 2. Normalized RCS cooling rate (3 Trains)

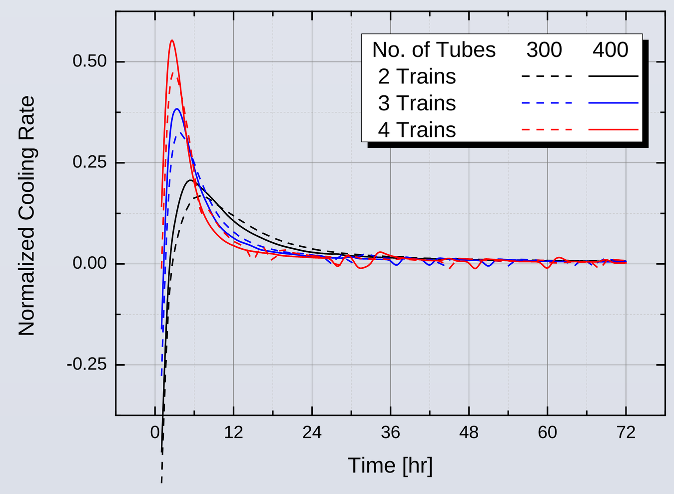

Fig. 4. Normalized RCS cooling rate (300/400 Tubes)

CONCLUSIONS

The preliminary calculation for the heat transfer area of the PHX was conducted. It was predicted that the number of tubes shall be 360 and the number of trains in operation shall be at least 3 to reach the safe shutdown condition. This paper will contribute to the design of the passive safety systems of the SMART Plus.

ACKNOWLEDGEMENT

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2) J.H. Moon, et al., Filling Ratio Effect on Thermal Performance of PRHRS for an Integral Reactor, Transactions of the KNS Autumn Meeting, Gyeongju, Korea, 2015.