

A STUDY ON PASSIVE CONTAINMENT COOLING CONDENSERS IN SBWR

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ABSTRACT

The passive containment cooling condensers (PCCC) are the crucial part of several new reactor designs, like European Simplified Boiling Water Reactor (ESBWR) and the SBWR. In a hypothetical accident, the pressurised steam non-condensable mixture from drywell is condensed in PCCCs, and condensate is returned to reactor vessel while non-condensable is vented through wetwell. In this study, in order to examine the performance of PCCCs, condensation with presence of noncondensable is investigated. Condensation with different noncondensable types and conditions is studied on a PCCC model, which is developed by using RELAP5 Mod3.2 computer code

INTRODUCTION

Condensation from steam-gas mixture inside tubes is an important technical problem in the design of passive containment cooling systems. In Simplified Boiling Water Reactor (SBWR), mixture of steam-noncondensable mixture resulting from possible accident is condensed passively in PCCCs. Each PCC condenser is formed by several vertical tubes connected to an upper plenum that receives the steam from a distributor and a lower plenum where the condensate, the uncondensed steam and the non-condensable gases (NC) are discharged. These PCC condensers are submerged in a large pool of water at atmospheric pressure [1].

As condensation takes place inside the condenser tube, a condensate liquid forms. Noncondensable gas, unable to pass into the water film, accumulates at the liquid-vapor interface, forming a gas-vapor diffusion layer through which the steam must pass by diffusion and convection, to be condensed. The accumulation of gas near the interface reduces the interface saturation temperature (corresponding to the interface vapor partial pressure) below the bulk saturation temperature (corresponding to the bulk vapor pressure). In pure steam condensation, liquid film provides the main thermal resistance to condensing heat transfer inside the tube. With the formation of a gas-vapor boundary layer, the mass transfer resistance between the bulk mixture and the condensing interface increases with increasing noncondensable gas concentration near the interface. If the gas concentration is sufficiently high, the gas-vapor layer becomes the main resistance to condensation heat transfer [2],

Model for RELAP5 Computer Code

The model for investigating the characteristics of condensation process with presence of noncondensable is developed. The description of the model and the relevant flow diagram is shown in the following figure.

The model consists of a condenser tube connected between upper and lower drum in which steam noncondensable mixture flows downward. Time dependent volumes are used to define the thermodynamic state of steam and the noncondensable. These volumes are denoted by 100 and 200, respectively. In the volume denoted by 300, steam and noncondensable gas are mixed and enter the condensation tube.

Condensation tube has 3.37-m. long, 5.08 cm. O.D. type 304 stainless steel tube with a 1.65-mm. wall thickness, with an 81-cm. adiabatic entrance followed by a 2.4-m. long condensing section and a short adiabatic exit section.

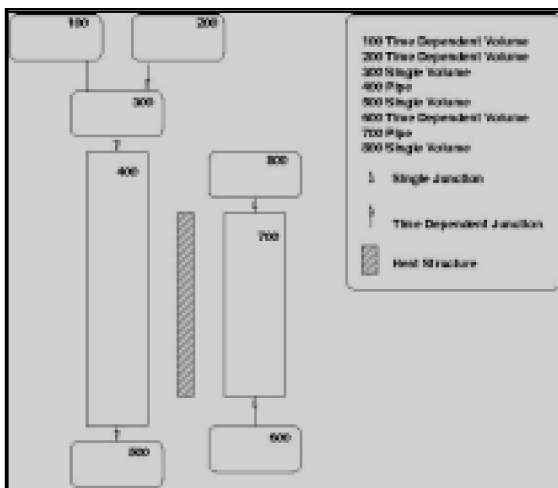


Figure 1. Flow Diagram for PCCC Model in RELAP5 Mod3.2

The components that are numbered with 600, 700 and 800 are used to define the cooling side of PCCC. The interaction between the pool side and the condensation side is maintained by using heat structure that defines the conduction heat transfer in condenser tube.

In this study, based on this model, the parametric study is performed to reveal the effects of noncondensable type, noncondensable fraction and inlet pressure of the mixture on performance of the condensation process inside the tube.

ANALYSIS

Effect of Noncondensable Type on Condensation: For the purpose of analysis, two types of noncondensable are studied to reveal their effects on the condensation. In each case, inlet

pressure of the steam-gas mixture and the noncondensable fraction in the mixture are kept constant. The case of pure steam condensation is also studied and the results are compared with the steam-gas mixture condensation. The variation of heat transfer coefficient respect to flow direction is shown in Figure 2. This figure shows how noncondensables deteriorates the heat transfer characteristics of condensation.

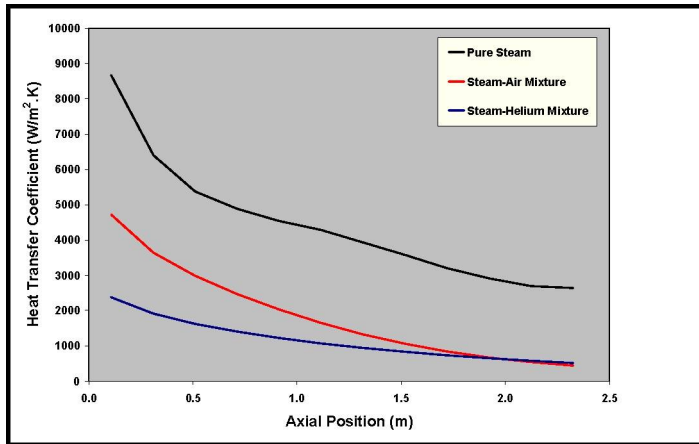


Figure 2. Effect of Different Type of Noncondensables on Heat Transfer Coefficient

This figure implies that presence of noncondensable greatly reduces the heat transfer coefficient. Especially, reduction in the heat transfer coefficient for helium is more significant than the air. The plot of variation of condensation heat flux also demonstrates the same fact as shown in Figure 2.

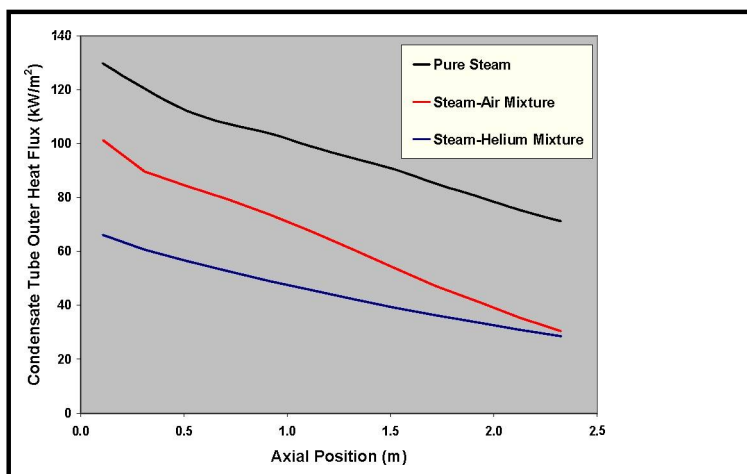


Figure 3. Variation of Condensate Heat Flux in Condensate Tube

The variation of heat transfer coefficient with noncondensable fraction is shown in Figure 4. As the figure implies, the increasing in the noncondensable fraction reduces the heat transfer coefficient because of increasing in gas layer between condensate and steam-gas mixture.

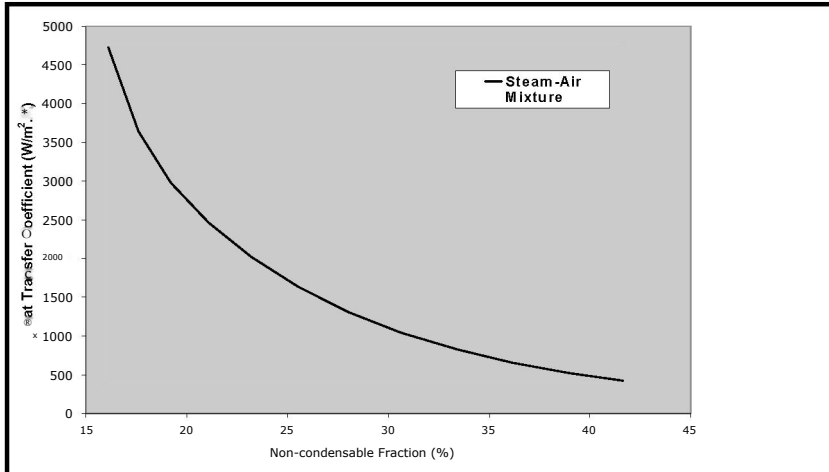


Figure 4. Variation of Heat Transfer Coefficient with Noncondensable Fraction

In this study, the performance of the PCC condensers are also examined under different operating conditions. For the purpose of analysis, different inlet pressure and noncondensable fractions of steam-air mixture is considered. At this point, efficiency of condensation process is defined as the ratio of the fraction of steam-gas mixture condensed in the tube. Following table summarizes the result of different runs:

Inlet Pressure = 400 kPa	Noncondensable Fraction 2 %	Efficiency 44 %
	Noncondensable Fraction 15 %	Efficiency 42 %
	Noncondensable Fraction 42 %	Efficiency 36 %
Inlet Pressure = 800 kPa	Noncondensable Fraction 2 %	Efficiency 61 %
	Noncondensable Fraction 15 %	Efficiency 53 %
	Noncondensable Fraction 42 %	Efficiency 47 %

CONCLUSION

In this study, condensation process in vertical tube immersed in a pool has been studied. The effect of noncondensables on the condensation of steam-noncondensable mixture was investigated and the reduction in heat transfer coefficient and condensation performance were verified based on the model developed by means of RELAP5 computer code.

Two types of noncondensable are considered namely air and helium. The results demonstrate that helium has greater effect on reduction of the condensation heat transfer rate. In lighter noncondensables, the increase in the gas layer between condensate and steam-gas mixture. Similar result was obtained by M.Soliman et.al [3].

It is also demonstrated that greater part of the condensation takes place in the upper part of the condensation tube. This is because of lower noncondensable fraction in this section respect to the rest of the tubes. The result can also be verified by means of the noncondensable quality variation inside the tube.

The effect of inlet pressure was examined. The efficiency of the condensation was studied for different noncondensable qualities. The results have demonstrated that increasing in the inlet pressure improves the efficiency of the condenser.

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