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Development of the Steam-Gas Pressurizer for REX-10

Jong-Won Kim,a Hyoung-Kyoun Ahn,a Goon-Cherl Park,a
a Dept. of Nuclear Engineering, Seoul National Univ., Seoul, Korea
E-mail : riaa99@snu.ac.kr

1. Introduction

As a part of a Regional Energy Reactor 10 MW_{th} (REX-10) Project in RERI (Regional Energy Research Institute), more stable, efficient and area-independent small-scaled reactor is investigated. Since this reactor will be located relatively near the residential area, it should have highly enhanced safety features compared with current nuclear power plants. REX10 reactor system is designed to be based on SMART (System-integrated Modular Advanced ReacTor) and the system pressure and capacity are determined properly for regional energy reactor. These integral reactor concepts are characterized to be the entire primary systems such as core, pumps, main heat exchangers (steam generators), pressurizer, etc. are arranged in a single pressure vessel. This reactor has enhanced safety because there is no LBLOCA; it endures less influence on the reactor pressure vessel and employ a passive system. Thus, the thermo-hydraulic analysis of safety for integral natural circulation system is introduced. Moreover, the study on the self-pressurized built-in steam-gas pressurizer for regional energy reactor is required.

From the viewpoint of pressurizer, additional systems such as heater, pressurizer cooler, spray and insulator are unavoidable to be used for a steam pressurizer or a gas pressurizer [1]. However, in case of a steam-gas pressurizer, additional systems are not required by using steam and noncondensable gas as a pressure-buffering material. Although the structure of steam-gas pressurizer is simple, the thermal-hydraulic phenomena in the steam-gas pressurizer are very complex [2]. However, there have been few investigations on the steam-gas pressurizer compared with the steam pressurizer. Though Russian Federation has developed the nuclear reactor with steam-gas pressurizer, the available data are very restrictive.

In this study, the experimental apparatus is designed to understand the main thermal-hydraulic behavior, the condensate heat transfer in the presence of noncondensable gas under high pressure for REX-10. In addition, the analysis by RETRAN-3D/NC is performed to compare with the experiment.

2. Methods and Results

In general, the condensate heat transfer at the wall is an important physical phenomenon in the pressurizer. In addition, it has been reported that the presence of noncondensable gas substantially decreases the condensation heat transfer. Since the system pressure in the steam-gas pressurizer is over 2.0 MPa, the heat transfer rates on the high pressure condition should be obtained for the analysis of the steam-gas pressurizer.

2.1 Design of Experimental Apparatus

Condensation heat transfer experiment under natural convection is designed to investigate the heat transfer mechanism of the mixture gas noncondensable gas and steam on the closed loop system. Nusselt correlation for the steam condensation is applied to produce the film condensation by cooling pipe wall [3]. The heater power is 20 kW and the maximum cooling capacity is 23 kW. The Reynolds number by Nusselt correlation is 2952.9 that is included the range of turbulent film condensation. Considering the heat exchange, the cooling water flows from top to bottom. By means of the experiment, the local heat transfer coefficients are presented by system pressure and noncondensable gas partial pressure. The measurement parameters are the temperature of cooling pipe surface and gas mixture, the pressure of system and noncondensable gas, and condensate rate. J-type thermocouples are applied to measure the temperatures and laser Raman measurement set is used to measure the density of noncondensable gas [4]. To calibrate the laser Raman measurement set the primary experiment of gas partial pressure is performed. Air/He gas mixture and He/N_2 gas mixture, $steam/N_2$ mixture are tested.

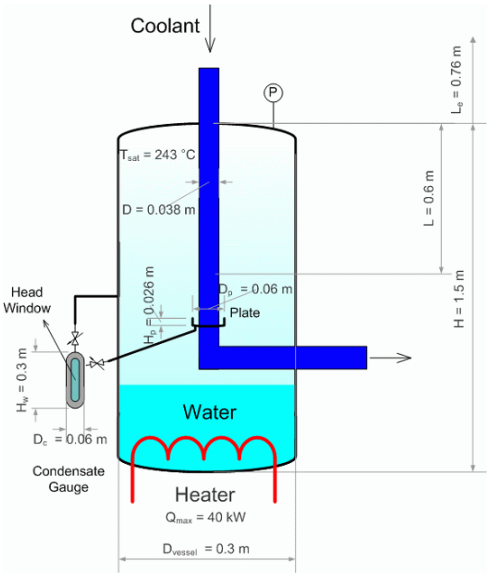

Figure 1. Schematic diagram of experimental apparatus

2.2 RETRAN-3D Analysis

The code simulation for experiment was conducted with the system analysis code, RETRAN-3D/NC [5]. The analysis results are expected to compare the condensate heat transfer coefficient with the results of experiment.

RETRAN-3D/NC has been developed based on the RETRAN-3D/INT considering two-region nonequilibrium model with noncondensable gas. The nodalization of the experimental apparatus for RETRAN-3D/NC calculation is shown in Fig. 2.

The model consists of single two-region fluid volume for a pressure vessel, ten volumes for a cooling pipe and heat structure to simulate the condensate heat transfer phenomena. The coolant flow was given using a fill junction model.

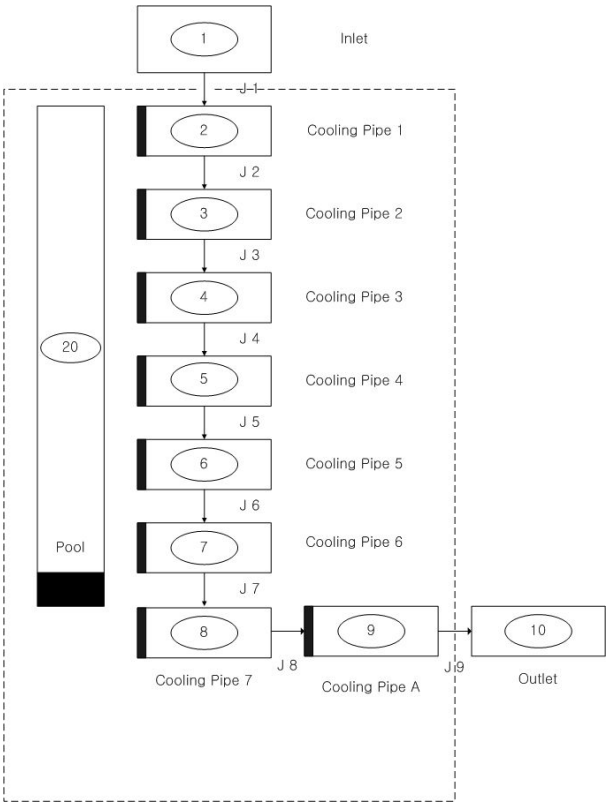

Figure 2. Nodalization of experimental apparatus for RETRAN-3D/NC analysis

From the results of RETRAN-3D/NC analysis, the initial condition to be applied to experiment can be obtained. Once the outlet temperature is determined, the condensate heat transfer coefficient can be obtained using the temperature difference between the inlet and outlet temperatures. As a result, the condensate heat transfer coefficient in the presence of noncondensable gas under high pressure will be obtained. These results will be compared with those of the experiment.

3. Conclusion

In order to study the thermal hydraulic phenomena, the condensate heat transfer characteristics of steam-gas pressurizer in REX-10, experimental apparatus was designed and the analysis using RETRAN-3D/NC was performed, too.

In the future, based on this work, the experimental study will be carried out to obtain the correlation of condensate heat transfer coefficient under high pressure. These results will be used to verify those of RETRAN-3D/NC analysis and understand the behavior of steam-gas pressurizer. Moreover, analysis code and advanced steam-gas pressurizer model for regional energy reactor by correlation of condensate heat transfer coefficient will be developed.

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