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Development of Thermal-Hydraulic Computer Program for a Steam Generator Cassette of an Integral Reactor

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1. Introduction

Steam generator cassette (SGC) of an integral type reactor is of a once-through modular type and installed on the annulus formed by the RPV and the core support barrel. The primary reactor coolant flows downward in the shell side of the SG tubes, while the secondary feedwater flows upward in the tube side. The secondary feedwater is evaporated in the tube and it exits the SG cassette nozzle header at a 40^{o}C superheated steam condition of 3.45MPa. The SGC nozzles for the feedwater and steam are designed to be a single structure located on the lateral surface of the RPV to reduce the vessel penetrations.

In this study, a thermal-hydraulic computer program for the SGC was developed, which is composed of several modules for each region of a SGC. Figure 1 shows the internal structure of SGC, which includes the steam and feedwater nozzles, module feedwater pipes and headers, flow restricting orifices, helically coiled tubes, and module steam pipes and headers. The developed program includes pressure drop and enthalpy rise routines for each part of a SGC, and an overall convergence checking routine.

2. Program Development and Results

The ONCESG is a thermal hydraulic design and performance analysis computer program for an once-through steam generator (OTSG) using helically coiled tubes. It has been developed and utilized for the optimal thermal design of the OTSG in KAERI [1]. It includes thermal-hydraulic models for the primary and secondary sides of the helical coil, and the coil wall. Secondary side of tube consists of an economizer, an evaporator, and a superheater region, each of which has a separate thermal-hydraulic model. The ONCESG calculates the exact location of the phase boundaries such as the boiling and dryout points, based on which numerical nodes are regenerated for every iteration steps.

The object of ONCESG is however confined to the effective helical coil region. To optimize the overall internal structure of a SGC from the viewpoint of the thermo-hydraulics and generate the interface requirements such as the steam temperature and feedwater pressure for the main steam and feedwater system designer, we need additional models for the other internal parts of a SGC. The program developed by Seo is adopted for the heat transfer and pressure drop evaluations of the module feedwater pipe [2]. The module feedwater pipe penetrates the upper part of the reactor vessel side wall and is connected to the bottom head of the SGC. First, the program calculates the heat transfer between the main flow and the bypass flow of the coolant inside the module feedwater pipe insulator and the cassette inner shell and then the heat transfer between the coolant bypass flow and the feedwater through the module feedwater pipes. The module feedwater pipe is divided into several regions depending on their geometric features in this calculation. New subroutine is developed for the module steam pipe and the cassette nozzle. Direct heat transfer between the incoming feedwater and out outgoing steam occurs in the cassette nozzle and steam is condensed there. Separate treatment is required for the heat transfer calculation in this region.

Figure 2 shows the calculation procedure and the convergence criteria. In the case of the energy equation, a calculation is carried out from the feedwater to the steam pipes. On the contrary, the pressure drop evaluation carried out from the steam to the feedwater pipes. The feedwater pressure and the internal ONCESG convergence test are utilized for the overall program convergence.

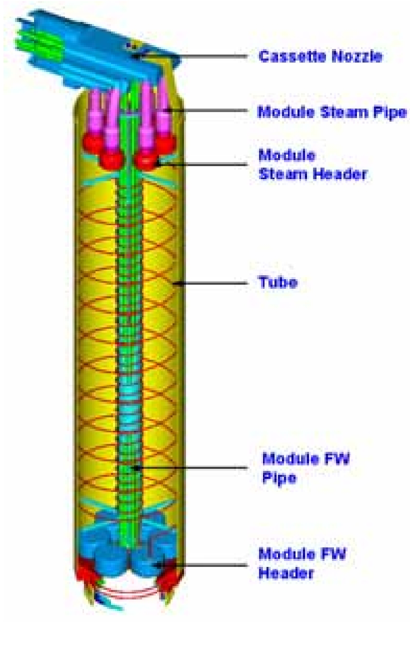

Figure 1. The internal structure of SGC.

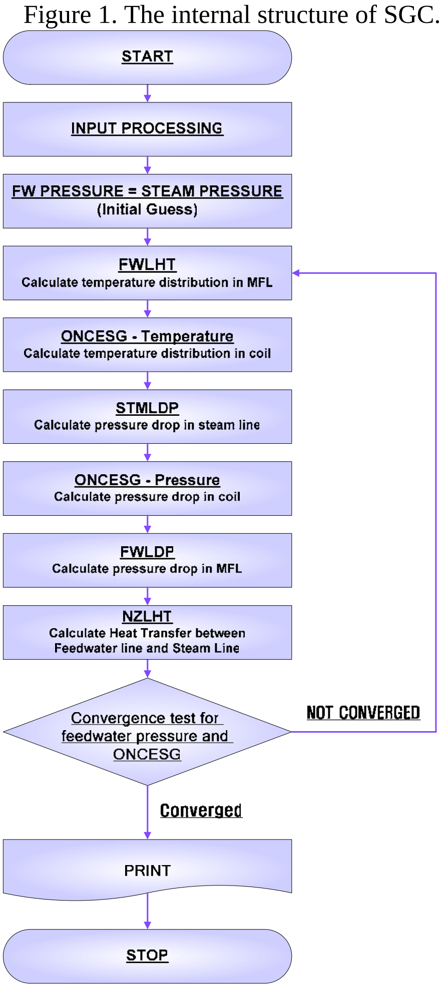

Figure 2. Calculation procedure.

The steam temperatures at the coil outlet and steam nozzle are shown as a function of the feedwater flow rate in Figure 3. The differences between two values are magnified at the lower feedwater flow rate, which is due to an increased heat transfer in the module steam pipe and the cassette nozzle. Pressure distributions inside the SGC are plotted in Figure 4. The figure shows that most of the pressure drop originates between the module feedwater pipe and the heated coil.

3. Conclusions

In this paper, a thermal-hydraulic computer program for a SGC covering the thermo-hydraulics of several internal structures was developed. The developed program can be utilized for an optimization of the overall internal structure of a SGC and a generation of the interface requirements for the main steam and feedwater system designer,

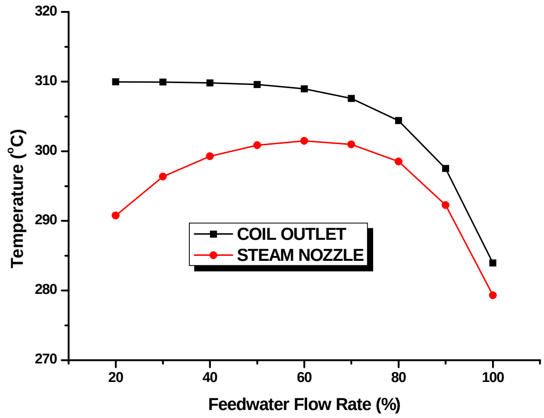

Figure 3. Steam temperatures at the coil outlet and steam nozzle as a function of feedwater flow rate.

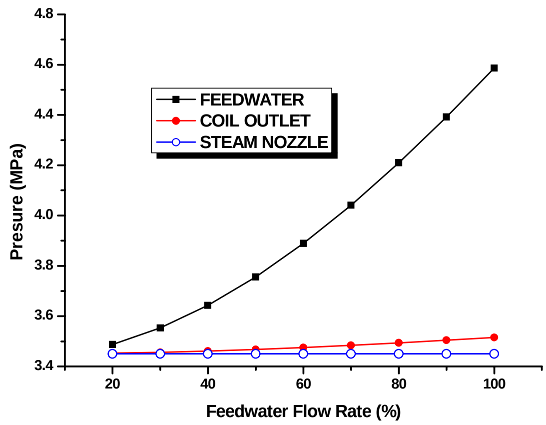

Figure 4. Pressure distributions inside the SGC as a function of feedwater flow rate.

REFERENCES

[1] J. H. Yoon, J. P. Kim, H. Y. Kim, D. J. Lee, M. H. Chang, “Development of a Computer Code, ONCESG, for the Thermal-Hydraulic Design of a Once-Through Steam Generator,”J. Nuclear Science and Technology, Vol. 37, No. 5, pp. 445~454 (2000).

[2] J. K. Seo, H. O. Kang, Y. I. Kim, J. H. Yoon, S. Q Zee, D.D. “Insulation Performance of a Tube-in-tube Modular Feedwater Line for an In-vessel Once-Through Steam Generator,” Proceeding of Korean Nuclear Society Autumn Meeting (2005).