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Preliminary Performance Analysis on APR+ PAFS Using RELAP5 and MARS Codes

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1. Introduction

International nuclear industry has been adopting a passive safety system to enhance safety and reliability of nuclear power plant with advanced technology. Domestic industry has been also developing a specific advanced reactor, so-called advanced power reactor plus (APR+), with passive auxiliary feedwater system (PAFS)[1]. The PAFS was introduced to replace an active auxiliary feedwater system (AFWS) completely. The system function is to remove the residual heat in the primary system like the AFWS does when the main feedwater system is unavailable.

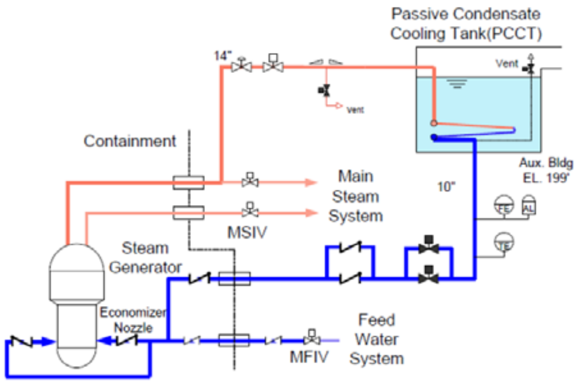


Fig. 1 Design concept of PAFS

PAFS consists of a passive condensate cooling tank (PCCT), a heat exchanger, valves, and pipes as shown in Fig. 1. When PAFS works, steam from steam generator is supplied and condensed into water in the heat exchange. And the water falls down by gravity and returns to the steam generator. This progress goes on repeatedly and it makes natural circulation possible in the system. The circulating flow removes continuously the primary residual heat without any active components.

The performance of PAFS depends on various thermo-hydraulic (TH) phenomena occurred in the system. So understanding these phenomena is required to analyze its performance with TH code such as RELAP5 or MARS which is a regulatory audit code. Licensee in the domestic industry has been conducting the performance analysis of the PAFS with RELAP5. So the analysis of MARS model with the same input was carried out and difference between two codes was compared in this study.

2. Heat Transfer in Condensate Heat Exchanger

In the PAFS, heat transfer is one of the most important factors to determine its performance. Especially condensation in the heat exchange tube induce two-phase flow which has a various flow pattern like an annular, wavy , and stratified flows as shown in Fig. 2.

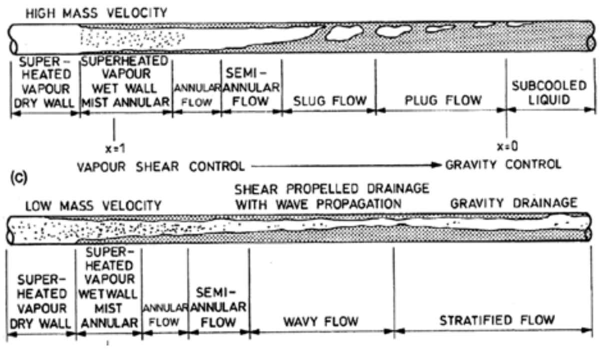


Fig. 2 Flow patterns in horizontal pipe

Another important modeling part is PCCT where pool boiling and natural circulation are occurred. Though there are some theoretical studies on it but the study with TH code such as RELAP5 and MARS is very rare.

3. RELAP5 and MARS Modeling

Nodalization as shown in Fig. 3 is for the PAFS model that licensee use in order to analyze its performance using RELAP5. So RELAP5 and MARS code input based on the nodalization was developed [2,3].

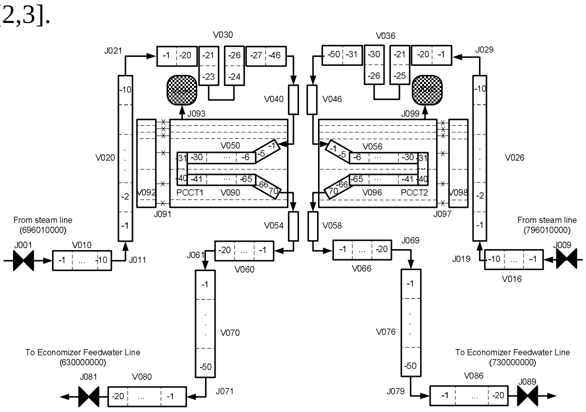


Fig. 3 PAFS nodalization

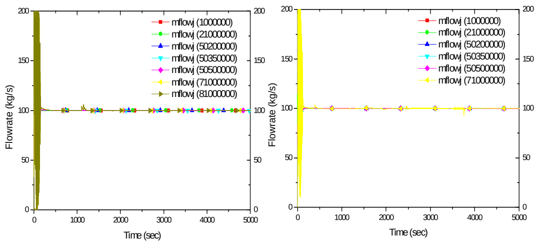
PAFS is composed of 2 independent trains which could be connected to each steam generators and two of PCCT are also located respectively. PAFS line consists of 10 volumes and PCCT consists of 3 volumes. Upper part of PCCT is filled with non-condensable gas. The developed PAFS RELAP5/MARS models were updated continuously with the newest design data.

We assumed that the inlet boundary of PAFS line be a constant steam flow fill junction and the outlet boundary be a constant pressure volume.

4. Analysis Results

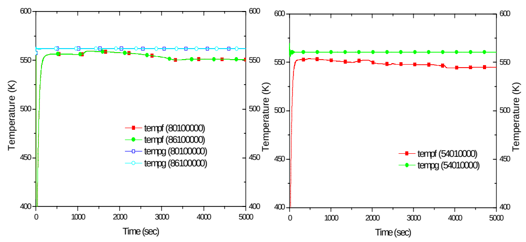
Fig. 5-9 show the analysis results for (a) RELAP5 and (b) MARS models of the PAFS. After code run, flow in PAFS line fluctuates initially and becomes stable as shown in Fig.5. Liquid temperatures in the outlet header rise rapidly up to about steam temperatures because the cold water in the line replaces condensed water in the heat exchange tube (Fig. 6). As the same reason, the void fraction also rise (Fig. 7). But there is a difference between the both models. The fluctuation phenomena of void fraction in the heat exchange tube for MARS model last longer than that for RELAP5 model.

In the PCCT the internal cross flow increases by natural convection and the water temperatures also increases. When boiling begins in the pool, the temperatures approach up to saturation temperature and stabilize as shown in Fig. 8 and 9. But the PCCT water temperatures of MARS model rise faster than those of RELAP5 model. It means that the heat transfer of MARS model is overestimated as compared with RELAP5 model.



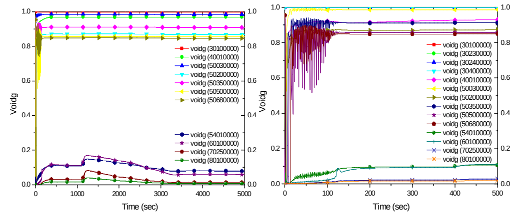
(a) RELAP5 (b) MARS

Fig. 5 Flow in PAFS line



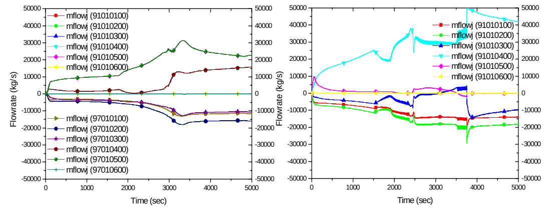
(a) RELAP5 (b) MARS

Fig. 6 Gas and liquid temperature in outlet header



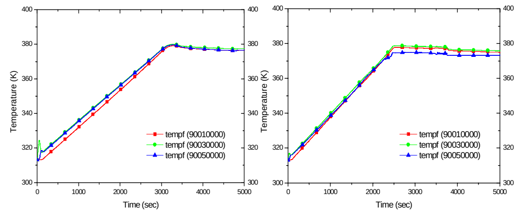
(a) RELAP5 (b) MARS

Fig. 7 Void fraction in PAFS line



(a) RELAP5 (b) MARS

Fig. 8 Cross flow in PCCT



(a) RELAP5 (b) MARS

Fig. 9 Water temperature in PCCT

5. Conclusions

Preliminary performance analysis for PAFS with RELAP5 and MARS codes has been carried out. Although there are some different results between RELAP5 and MARS models, the results show that PAFS could have a sufficient performance to remove the residual heat in the primary system. And it has been found that the PAFS performance is affected by various thermo-hydraulic phenomena like condensation heat transfer, natural convection, etc. Further study is required to find out the cause for difference in the analysis results of two codes.

6. Acknowledgements

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REFERENCES

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