Discussion on RELAP5 and RETRAN3D Modeling for Passive Condensate Cooling Tank of Passive Auxiliary Feedwater System in APR+

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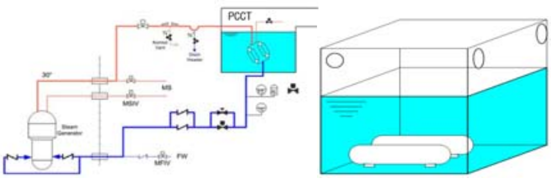
1. Introduction

Domestic nuclear industry has started the development of APR+ as a Korean specific reactor for the export strategy. In the development of APR+ a passive auxiliary feedwater system (PAFS) has been considered as a noticeable candidate of improved design. The outline of PAFS and passive condensate cooling tank (PCCT) containing horizontal heat exchanger is shown in Fig. 1[1].



(a) PAFS (b) PCCT

Fig. 1 Outline of PAFS and PCCT

For the successful design of PAFS, performance analyses or safety analyses are prerequisite using best estimate thermal hydraulic codes such as RELAP5 or RETRAN3D. Because of the inherent features of RELAP5 or RETRAN3D, pool model and condensation in horizontal tube have not been well-setup nor widely studied.

This paper discusses about the PCCT phenomena including steam condensation in horizontal tube and pool heat transfer, and RELAP5 and RETRAN3D modeling.

2. Literature Survey of Past Works

2.1 Condensation in Horizontal Tube Inner

The progress of steam condensation in horizontal tube goes from vapor shear-controlled flow to gravity-controlled flow. In vapor shear-controlled flow the typical flow pattern is annular flow, and in gravity-controlled flow, wavy and stratified flows. In higher steam velocity terminal flow pattern are slug and bubbly flows, and in slower steam velocity, wavy or stratified flow [2].

More systematic approach was achieved by the flow regime map by Baker as mentioned by Bell [2]. Baker's map is composed of weighted steam mass flux and weighted liquid mass flux. Condensation locus was explained by Bell's overlay method. However, Palen et al. pointed out the discrepancy of the locus from experiment [3].

Tandon's condensation regime map seems most plausible, which comprises of void fraction and quality weighted flowrate [4]. RELAP5 also adopts Tandon's regime map in ECCMIXER component for the accurate calculation of condensation separately from its original flow regime map [5].

2.2 Pool Model

There are only limited literatures which discuss on the modeling of pool circulation and heat transfer phenomena using best estimate thermal hydraulic code such as RELAP5 or RETRAN3D [5,6]. Moreover, we have not found any literature about RETRAN3D modeling.

Boyer et al. discussed on the modeling of vertical tube inner condensation using RELAP5 [7]. However, they only focused on the condensation in the tube inner and the pool seemed just as heat transfer boundary. They found that smaller node would increase the condensation rate, so node size should be determined by experiment.

Reference 8 discusses about RELAP5 modeling of PCCT. In this reference the heat exchanger was vertical style different from current horizontal one. 4 modeling methods were introduced; single volume model, three pipes model with multiple cross flows, three pipes model with top-bottom cross flow model, and two pipes model with top-bottom cross flow model. Among these models, three pipes model with top-bottom cross flow model was stated as optimal one. However, this model is expected to reveal its limitation when the water surface decreases under the top-cross flow junction, because the pool circulation cannot be achieved. This report mentioned that effect of the heated channel area was not large.

3. RELAP5 Assessment

3.1 Modeling and Performance Test

Nodalizations for RELAP5 PAFS and the PCCT are shown in Fig. 2. In this figure only 6 volume model is shown, however, 3 volume model and 10 volume model were also assessed. Upper part of PCCT is filled with noncondensable gas. PAFS inlet was models as constant steam flow junction and the outlet as pressure boundary. The representative results, void fraction in tube lower part, are shown in Fig. 3. 6 volume model and 10 volume model show only just a little difference. That is, 6 volume model is optimized one.

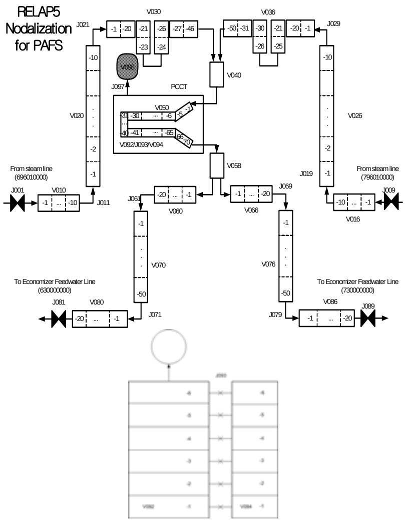
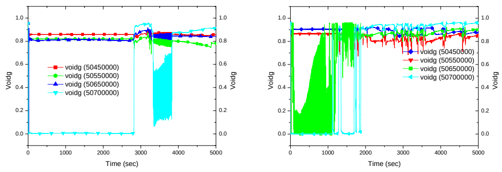
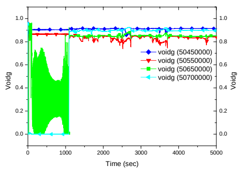


Fig. 2 RELAP5 PAFS and PCCT Model



(a) 3 volume model (b) 6 volume model



(c) 10 volume model
Fig. 3 RELAP5 Results (Tube Lower Part Void Fraction)

3.2 Heat Transfer Analysis

PCCT undergoes single phase pool circulation heat transfer in earlier stage and pool boiling in latter stage. Prediction accuracy of RELAP5 was checked by independent heat transfer coefficient calculation using different correlations. In actual, the PCCT showed nucleate boiling even in earlier stage at which the pool void fraction was nearly zero, and pool boiling in later stage (in RELAP5 this pool boiling is also identified as nucleate boiling of saturated state). Heat transfer coefficients were similar in hand calculation and RELAP5 calculation.

4. RETRAN3D Assessment

Nodalization for RETRAN3D PAFS and the PCCT are shown in Fig. 4. For the ease initialization, artificial valves are modeled. Noncondensable gas in upper part of PCCT makes it difficult to get the stable initial state. Through the null transient calculation actual steady state was obtained. Representative results are presented in Fig. 5. This figure shows similar result with RELAP5.

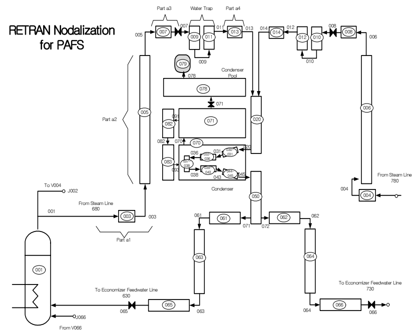


Fig. 4 RETRAN3D PAFS and PCCT Model

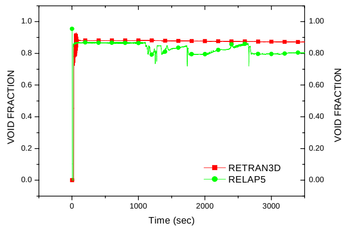


Fig. 5 Comparison of RETRAN3D Results to RELAP5 Results (Tube Lower Part Void Fraction)

5. Conclusions

This paper presents intensive literature surveys on the steam condensation phenomena in horizontal tube inner and pool model of RELAP5. Based on these studies RELAP5 and RETRAN3D pool model was successfully setup.

6. Acknowledgements

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