Simulation of GAMMA and RELAP5 of Gas Natural Circulation Loop

J.I. Lee and H. C. No
Dept. of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology,
373-1 Guseong-dong Yuseong-gu, Daejeon, 305-701, Republic of Korea
E-mail: jeongiklee@kaist.ac.kr, hcno@kaist.ac.kr

1. Introduction

GAMMA code is being developed by KAIST and KAERI [1] as a computational tool for predicting various transients those can potentially occur in a high temperature gas cooled reactor. The code has a capability of analyzing multi-dimensional multi-component mixture and includes models for friction, heat transfer, chemical reaction and multi-component molecular diffusion. As a part of the code development effort, steady state natural circulation data with nitrogen and carbon dioxide [2] are compared to numerical predictions by two computer codes – the system analysis code GAMMA and RELAP5-MOD3. RELAP5-MOD3 has gained modeling capability of a gas system by incorporating gas properties and additional models, which were implemented by Idaho National Laboratory.

Before we present our results, it should be noted that the operated heat transfer regime for presented data is in the deteriorated turbulent heat transfer (DTHT) regime. The deterioration of the turbulent heat transfer occurs due to two effects: (1) buoyancy effect and (2) acceleration effect. Both effects reduce the turbulence generation near a heated wall when the heating rate is high. Details on the physics are explained in Ref. [3] with the presentation of governing non-dimensional numbers.

2. GAMMA and RELAP Modeling

Since the experimental facility and the measured data are described in detail in Refs. [2, 3] they will be omitted in this summary. Table I briefly summarizes the experimental conditions.

Table I: Experimental Conditions

Run #	Gas	Pressure (MPa)	Inlet Re	Mass flow rate (kg/sec)	Inlet Temperature (K)
1	N2	0.496	4,591	1.043×10^{-3}	299.6
2	N2	0.695	6,608	1.495×10^{-3}	297.9
3	N2	0.562	7,452	1.666×10^{-3}	296.5
4	N2	0.401	4,343	0.978×10^{-3}	295.4
5	CO2	0.271	6,106	1.155×10^{-3}	294.7
6	CO2	0.374	10,073	1.892×10^{-3}	294.1
7	CO2	0.534	16,336	3.049×10^{-3}	293.7

Figure 1 shows the nodalization of the experimental facility as modeled in GAMMA and RELAP5-MOD3. The modeling strategy and details are presented in Ref. [2], therefore they will not be repeated here.

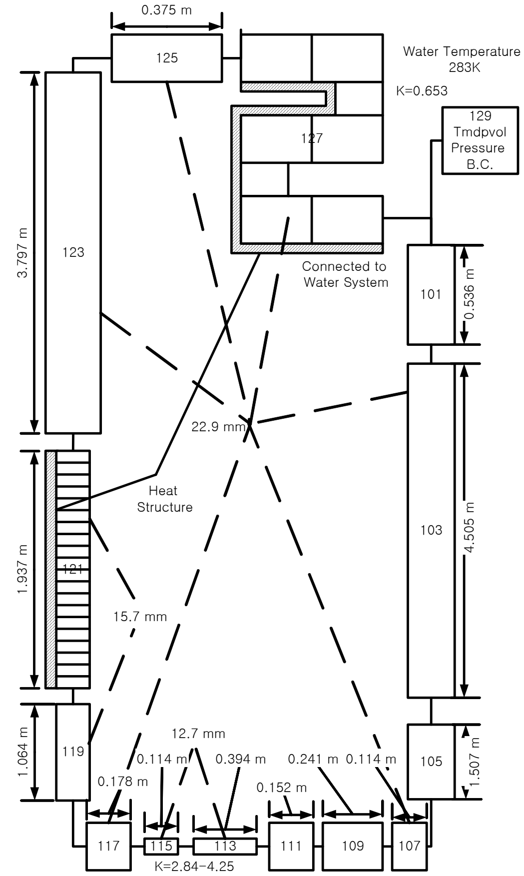

Fig. 1. Nodalization of the Experimental Facility for GAMMA and RELAP5-MOD3 Inputs

4. Comparison of Results

Figures 2 through 8 show the results of comparison in terms of the wall temperature and the bulk temperature of the test section.

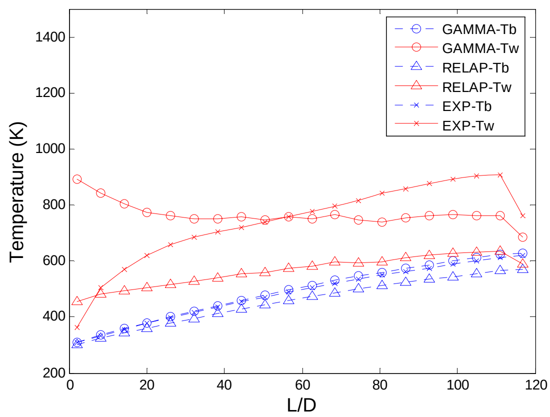

Fig. 2. Run #1 GAMMA vs. RELAP vs. Experiment

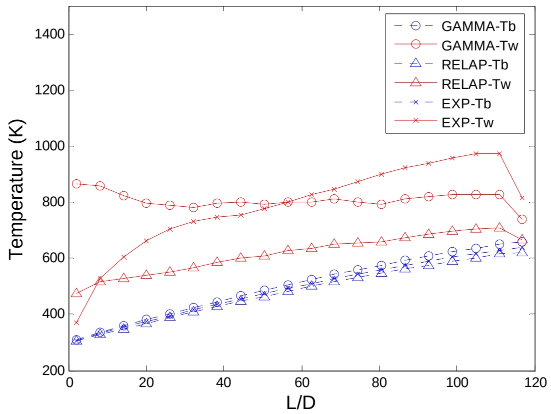

Fig. 3. Run #2 GAMMA vs. RELAP vs. Experiment

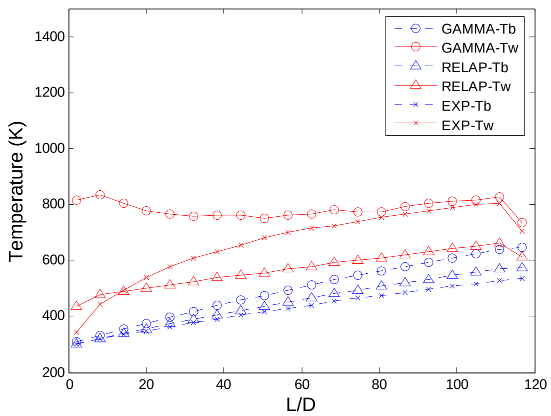

Fig. 4. Run #3 GAMMA vs. RELAP vs. Experiment

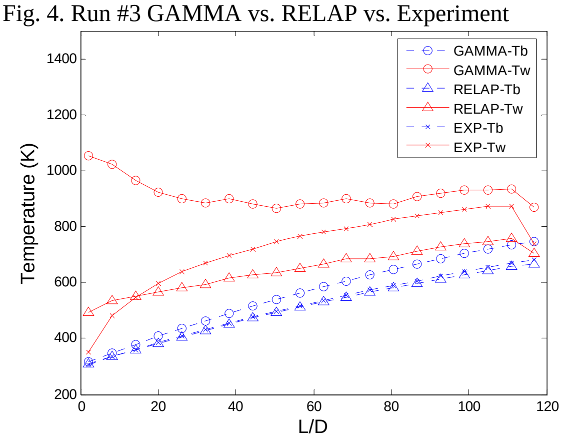

Fig. 5. Run #4 GAMMA vs. RELAP vs. Experiment

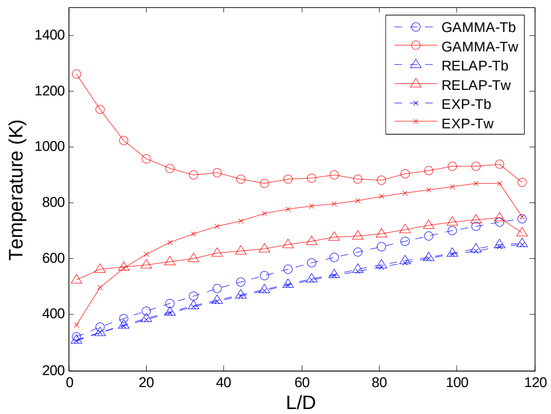

Fig. 6. Run #5 GAMMA vs. RELAP vs. Experiment

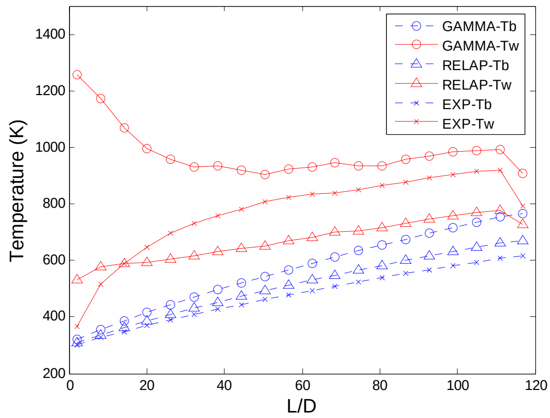

Fig. 7. Run #6 GAMMA vs. RELAP vs. Experiment

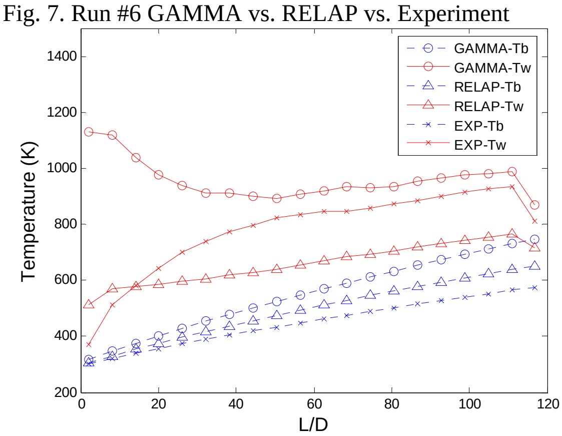

Fig. 8. Run #7 GAMMA vs. RELAP vs. Experiment

5. Discussion

The major causes for discrepancies are due to: (1) as described in Ref. [2], insufficient information of friction factor in the DTHT regime causes the flow rate discrepancy, which is reflected in the bulk temperature profile. Thus, both codes require upgrading the friction factor package after the correlation is developed for the DTHT regime. (2) Heat transfer package requires modification too. Even though GAMMA's original heat transfer package includes mixed-convection regime, which is the other name for the DTHT, still the result shows that the included heat transfer package performs with insufficient accuracy. However, GAMMA is more conservative than RELAP, since RELAP only has forced convection heat transfer package.

REFERENCES

[1] H. S. Lim, "Transient Multicomponent Mixture Analysis for Air Ingress Phenomena in a High Temperature Gas-cooled Reactor," KAIST Ph. D. thesis, 2005

[2] J. I. Lee and P. Hejzlar, "Experimental and Computational Analysis of Natural Circulation Loop," International Congress on Advances in Nuclear Power Plants, Paper 7381, Nice, France, May 13-18, 2007.

[3] J. I. Lee, P. Hejzlar and M. S. Kazimi, "Deteriorated Turbulent Heat Transfer of Gas Up-flow in a Circular Tube: Experimental Data," International Journal of Heat and Mass Transfer, Vol. 51. 3259-3266, 2008