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Assessment of the Radiation Enclosure Models in SPACE and RELAP5 with GOTA Test 27

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1. Introduction

SPACE (Safety and Performance Analysis Code) [1] for nuclear power plant has been developed to calculate the transient thermal-hydraulic response of PWRs that can contain multiple types of fluids. The thermal-hydraulic behavior during a loss of coolant accident (LOCA) has been investigated mostly by one-dimensional (1-D) SPACE. However, the predictions using 1-D code would be unrealistic if there is a vigorous influence of three-dimensional (3-D) effects. Especially, without explaining 3-D effects such as the change of fuel rod/guide tube thermal behavior as a result of the radiation heat transfer, the 1-D code could predict an unrealistically high peak clad temperature. A useful function to simulate the wall-to-wall radiation heat transfer is implemented in the SPACE and RELAP5 codes. This paper discusses the assessment results of the radiation enclosure model of SPACE and RELAP5.

2. Model Assessment

Evaluation of the radiation models of SPACE and RELAP5 was twofold: to select an experiment according to the wall-to-wall radiation heat transfer and to perform the analysis of the calculations.

2.1 GOTA Radiation Test 27

The GOTA test facility in Sweden [2] reported steady state data taken in a vertical 8 x 8 rod bundle. The main objectives of the experiment were to identify the function of the emergency core cooling system (ECCS) which is to prevent or limit damage to the reactor core in case of a LOCA. The test loop consisted of the pressurizer to regulate the pressure, the main circulation pump, the cooler to control the fluid temperature, and the steam generator (SG) to supply the steam.

This test was remarkably useful for evaluating the radiation calculations since the radiation test data were obtained by setting the bundle power to a constant value at high temperatures with large temperature gradients in stagnant steam at atmospheric pressure inside the channel box (rod bundle housing). The bundle was enclosed in a canister, which acted as a heat sink because the outside temperature was maintained at 373.0 K by external cooling via the running water on the channel box outside wall. The bundle power was adjusted to maintain the hottest rod at the bundle mid-plane at 1224.0 K.

A radial variation of the power density was obtained by the power fractions for all rods shown in the Fig. 1. The rod and box temperatures were recorded when they reached a steady state value. During steady state all the rod power was being absorbed by the channel box through radiation heat transfer.

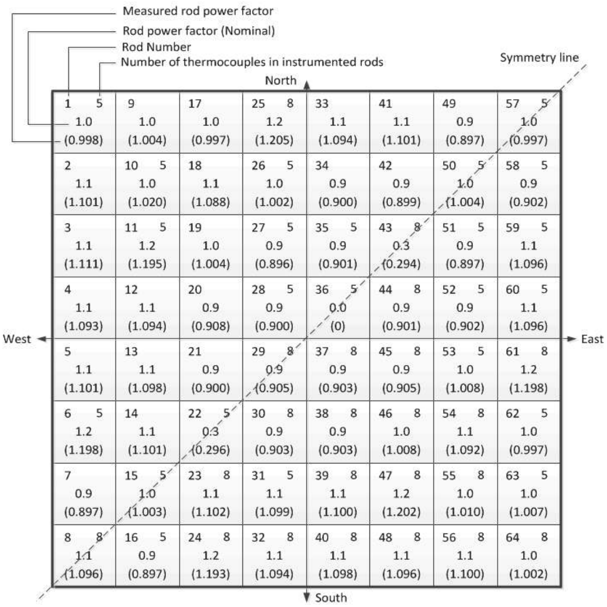

Fig. 1. Radial heat flux distribution of GOTA experiment [2]

2.2 Description of the Input Model

Fig. 2 shows the nodalization diagram for the GOTA test input model. As shown in this figure, the hydraulic components included in this input model were a pipe (test section, Component 139) and two temporal face boundary conditions (TFBCs, Components 129 and 149) at the inlet and outlet of the test section, respectively. The pipe consisted in a cell filled with the saturated steam at atmospheric pressure. The heat structures (Components 211-01, 222-02, 233-03, 244-04, 255-05, and 266-06) were attached to the pipe.

The bundle was modeled at the mid-plane by having six heat slabs. All rods could have been modeled but for practical reasons similar surfaces were combined against the radial heat flux of Fig. 1. The 64 rods were grouped into five heat structures as was done in Reference 3, as shown in Fig. 3, and the canister wall was the sixth heat slab. The RELAP5 model in Fig. 2 is identical to that excerpted from Reference 3.

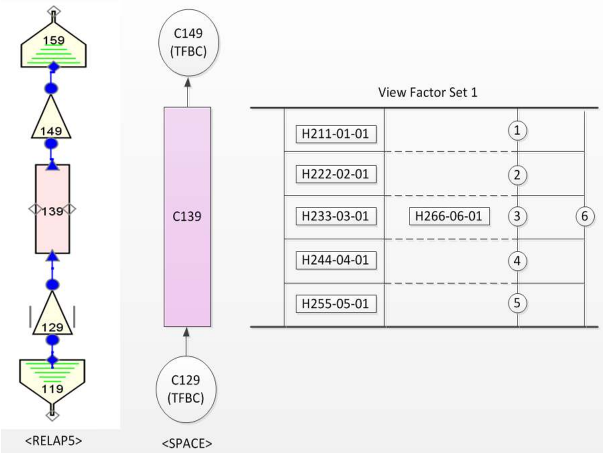

Fig. 2. SPACE and RELAP5 Nodalizations for GOTA Test 27

The bundle diagonal was a line of symmetry therefore all rods were not presented in Fig. 3. Group 5 on the diagonal was a peculiar group because it stood for a water rod and two low power rods. The other groups followed a pattern according to the radial power fraction. The view factors were obtained from the RELAP5 model [3] with the same six heat structures. The emissivity for all surfaces in the GOTA bundle was 0.67, as recommended in Reference 2.

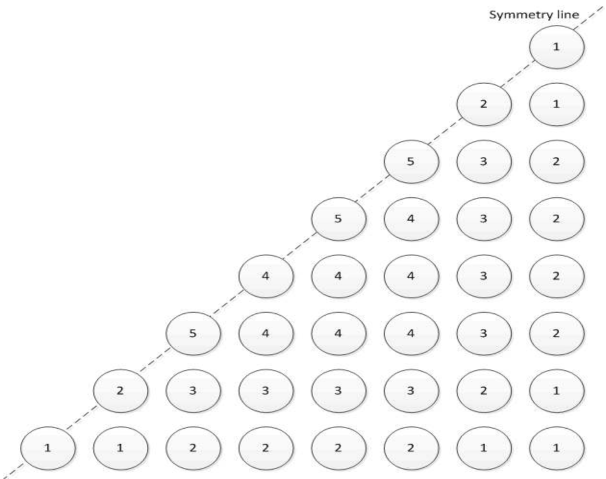

Fig. 3. GOTA Test 27 Rod Groupings for SPACE [3]

2.3 Description of the Codes

The SPACE code is based on the version 2.16 distributed by KHNP [1]. In order to perform the simulation of the GOTA test 27, it was necessary to modify the SPACE code. There was the subroutine for an input process corresponding to the radiation model, the inp_check function of the RadEncData Class, contained in a vulnerable algorithm to figure out the reciprocity rule of the view factor. In this study, the calculation of RELAP5 was also performed with the radiation model using RELAP5 based integrated code (RBIC) version 3.3gl [4].

2.4 Results

From the code-to-data and code-to-code comparisons, shown in Fig. 4, the surface temperatures of the bundle were evaluated. The average of the measured rod temperature for each group was compared with the SPACE and RELAP5 calculations along all five rod groups. The average error predictions of SPACE and RELAP5 were less than 10 K and 16 K, respectively. The calculated surface temperatures of the SPACE code as well as the RELAP5 code were in excellent agreement with the experiment data.

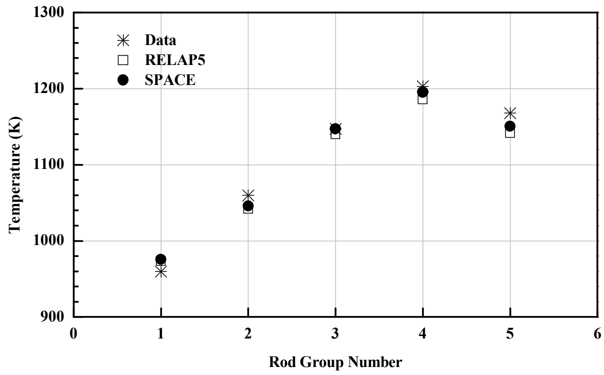

Fig. 4. Comparison of GOTA Test 27 data with the predictions by SPACE and RELAP5

3. Conclusion

The capability of handling wall-to-wall radiation problem of the SPACE and the RELAP5 codes has been evaluated using the experimental data from the GOTA test facility. At the top of the bundle, the maximum errors of SPACE and RELAP5 are less than 1.6% and 2.3%, respectively. As noted, there is a small discrepancy between the calculated results and experimental data except for the predictions near the top of the test section. Hence, the averaged percent errors of SPACE and RELAP5 are on the order of 1.0% and 1.5%, respectively. Overall the agreement between the SPACE and RELAP5 solutions and the experimental data is excellent.

REFERENCES

[1] S.J. Ha, C.E. Park, K.D. Kim, C.H. Ban, Development of the SPACE code for Nuclear Power Plant, Nuclear Engineering and Technology, Vol.43.pp. 45-62, 2011

[2] L. Nilsson, L. Gustafson, R. Harju, Experimental Investigation of Cooling by Top Spray and Bottom Flooding of a Simulated 64 Rod Bundle for a BWR, STUDSVIC/RL-78/59, Norhav S-406, June 30 1978

[3] R.W. Shumway, ATHENA Radiation Model, EGG-TFM-7925, EG&G Idaho Inc., October 1987

[4] Information Systems Laboratories Inc., U.S. Nuclear Regulatory Commission, RELAP5/MOD3.3 Code Manual Volume II: Appendix A Input Requirements, NUREG/CR-5535/Rev P3-Vol II App A, March 2006