The Specific Analysis and Evaluation for APR1400 Containment Using GOTHIC 3-D Model

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1. Introduction

The APR1400 have adopted several new design concepts in order to improve the plant safety functions during a postulated accident. The IRWST(In-Containment Refueling Water Storage Tank) is one of those design concepts of APR1400. It is located at the bottom of containment building and isolated from upper compartments of large free volume by pressure relief damper(PRD) having limited flow areas. Due to this design feature, the single-volume approach used in evaluation model for prediction of containment pressure and temperature transients has the limitations. Especially, the steam condensation on IRWST pool surface which is expected to affect on the containment pressure, can not be predicted with this approach [1].

Thus in this study, the detailed modeling of APR1400 containment building was performed by containment code GOTHIC code 6.1b [2][3].

The purpose of this study is to assess the influence of the IRWST and the PRD on back pressure and temperature in APR1400 containment building using GOTHIC which can also predict the steam condensation on IRWST pool surface.

2. Modeling of APR1400

In order to investigate the influence of IRWST and PRDs on back pressure and temperature in containment, the design features of APR1400 reactor and containment design data were reviewed and selected for input model necessary for containment back pressure analysis. Thus two–compartments(LPM 2-node), multi-compartment and detailed 3-dimensional GOTHIC model were developed and assessed to predict the steam condensation on IRWST pool surface.

2.1 GOTHIC Analysis Model

In order to investigate the influence of IRWST and PRDs on back pressure and temperature in containment, multi-compartment model for GOTHIC 6.1b code was developed based on APR1400 design data[4]. Fig. 1 depicts the multi-compartment which divides the space of containment building into 42 compartments. And also, in order to closely evaluate TH phenomena in the IRWST, three-dimensional (3-D) model for IRWST was generated because of a symmetric layout, pump, and suction sump.

Figure. 2 represents the 3-D GOTHIC model(R) and division concept (L) of IRWST.

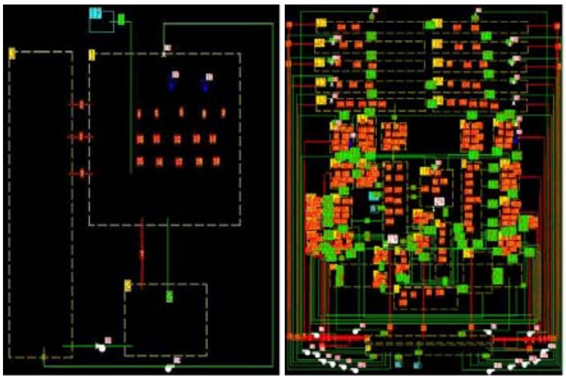

Fig. 1 GOTHIC LPM 2-node model(L) and multi-compartment model(R) for APR1400 containment

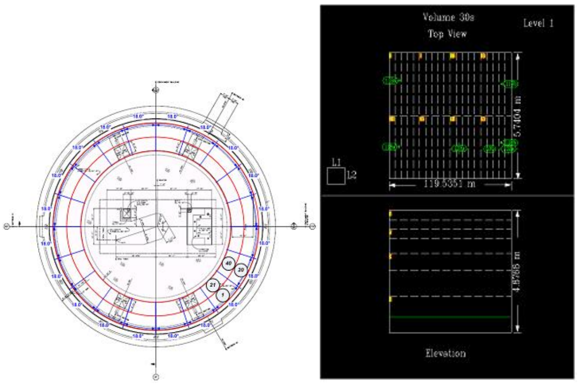

Fig. 2 Division concept(L) and 3-D model(R) for IRWST of APR1400

2.2 Initial and Boundary Conditions

For the containment, it is assumed that temperature is 283.15 K, pressure is 14.121 psia, and relative humidity is 90 %, respectively. And initial IRWST cooling water level is set to 11.5 ft. These input data are same as those of CONTEMPT4.

2.3 Control Volume

The APR1400 containment building is a pre-stressed cylindrical structure of concrete which has net free volume of 3.343×10^6 ft^3 as a maximum. IRWST is annular concrete structure located at the bottom of the containment and is connected to other containment compartments through four PRDs, and has nominal free volume of 1.182×10^5 ft^3. The altitudes of lower and upper floor are 81 ft and 97 ft, respectively.

2.4 Passive Heat Sinks

It is very important Which heat transfer model is used in the code when analyze pressure of containment. Generally, GOTHIC recommends to use 'Direct' heat transfer model and Its condensation heat transfer model is Uchida's one. In this study, to investigate the condensation effect, various calculation models such as 'Tagami-Uchida', 'Uchida' and 'Gido-Koestel' were applied.

2.5 Design Features of PRDs

The PRDs are located at the lowest floor of annular containment compartment and separated approximately 90° between PRDs. The net flow area for each PRD is designed to be 36 ft^2. When pressure difference between containment and IRWST reaches 0.5 psia, PRD is opened, allowing steam and air flows on both sides.

3. Analysis Results

3.1 Results of preliminary analysis

Fig. 3 and 4 depict various results of preliminary analysis for LPM 2-node and multi-compartment model, respectively. As shown in Fig. 3, in containment, initially pressure and flow-rate increase dramatically because of the RCS mass and energy release. And then, they decrease owing to containment spray operation. Fig. 4 shows, the results of various condensation heat transfer model. In case of this, Gido-Koestel condensation heat transfer model was more conservative than other models.

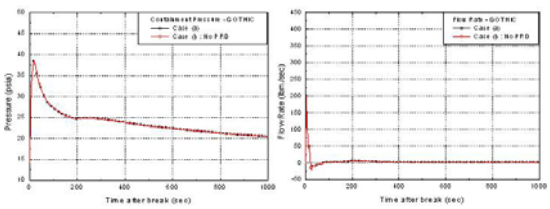

Fig. 3 GOTHIC LPM 2-node model(preliminary analysis)

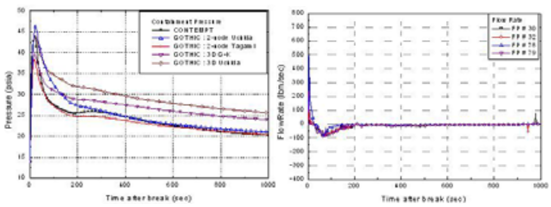

Fig. 4 GOTHIC multi-compartment model (preliminary analysis)

3.2 Results of CFD analysis

When the accident occurs hot steam is released from RCS and then enters into IRWST. In early stage, steam flow into the PRDs rapidly but the end of this stage, about 50s later, 2 of 4 PRDs release into containment. This phenomena are confirmed by CFD analysis as shown in Fig 5 and 6 that show steam fraction in IRWST after 10s and 100s respectively.

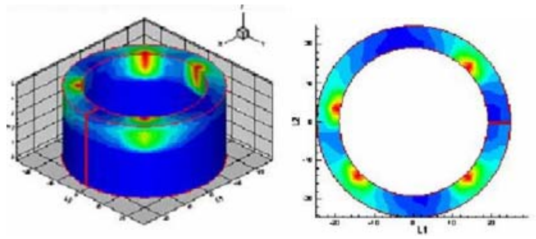

Fig. 5 Steam fraction in IRWST after accident (10s later)

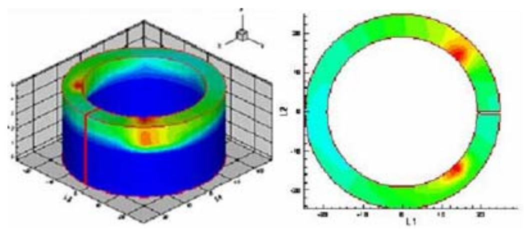

Fig. 6 Steam fraction in IRWST after accident (100s later)

4. Conclusions

In order to investigate the influence of IRWST and PRDs on back pressure and temperature in containment, LPM 2-node model and multi-compartment model for GOTHIC 6.1b code were developed based on APR1400 design data. With these models and various condensation heat transfer models, preliminary calculation was performed to analyze the effects of steam condensation on IRWST water pool and the functioning of pressure relief damper. In this analysis, a variety of initial and boundary conditions were applied.

The present analyses showed that the pressure relief damper have a little effect on pressure distribution between upper compartment and IRWST irrespective of its operating condition. Steam condensation on pool surface could not be distinct in the thermally stable condition. In other word, it was not effective in IRWST atmosphere due to low steam and high non-condensable concentrations.

REFERENCES

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