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Investigation of the Condensation Effect at IRWST Pool Surface on Containment Back Pressure in APR1400 Containment

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1. Introduction

The APR1400 has several new design concepts in order to improve the plant safety functions during a postulated accident. The In-Containment Refueling Water Storage Tank (IRWST) is one of the new design concepts of APR1400 and installed at the bottom of containment building to promote the plant safety functions by simplifying emergency core cooling water source and preventing release of the fission product during an accidents.

This design feature, however, brings about uncertainty factors which may necessitate conventional prediction of temperature and pressure of containment building improved or revised under accident conditions. The hot steam which is released from RCS break enters into the IRWST through four Pressure Relief Dampers (PRDs). It is expected to be condensed with water stored in IRWST, colder than incoming steam.

The purpose of this study is to examine closely the influence of the condensation effect at IRWST on containment back pressure in APR1400 containment building using the GOTHIC code[1] which can predict the steam condensation on IRWST pool surface.

2. Analysis Method

2.1. Review of APR1400 Design Features

The APR1400 containment building is a pre-stressed cylindrical structure of concrete which has net free volume of 3.3×10^6 ft^3 as a maximum. The altitude of lower floor is 100 ft and maximum height of the upper part is 329.5 ft. IRWST is annular concrete structure located at the bottom of the containment and is connected to other containment compartments by four PRDs, and has nominal free volume of 117,416 ft^3. The altitudes of lower and upper floor are 81 ft and 97 ft, respectively [2].

The PRDs are located at the lowest floor of annular containment compartment and have a configuration of separation of 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.

2.2. Analysis Model

In order to investigate the influence of IRWST and PRDs on back pressure and temperature in containment, multi-compartment model for GOTHIC 6.0 code was developed based on APR1400 design data[2]. Fig. 1 depicts the two-compartment (separated) model which divides the space between IRWST and containment.

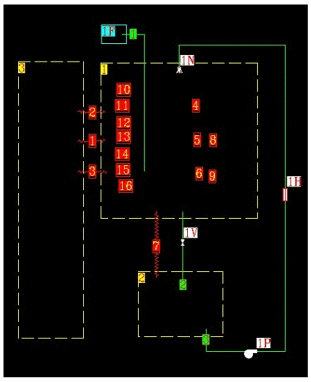

Fig. 1. GOTHIC separated model for APR1400 containment

Also, three-dimensional (3-D) model for IRWST was generated because it is not symmetric considering location of sparger, pump, and suction sump. Fig. 2 represents the 3-D GOTHIC model of IRWST.

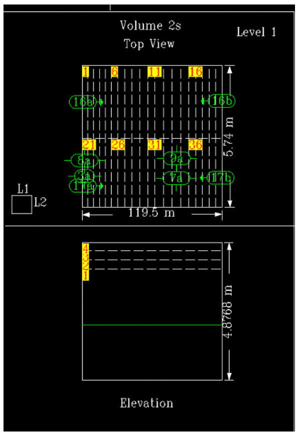

Fig. 2 GOTHIC 3-D model for IRWST

2.3. Analysis Conditions

The ESFs considered in this study are two trains of containment spray systems and safety injection systems, respectively. For analysis purpose, maximum allowable passive heat sinks are applied in consistency with material properties. The data from design basis accident are used for RCS mass and energy release.

For the containment, it is assumed that temperature is 50 °F, pressure is 14.7 psia, and relative humidity is 90 %, respectively. And initial IRWST cooling water level is set to 11.5 ft.

Details of GOTHIC modeling and related assumptions are presented in Reference 3.

3. Analysis Results

Fig. 3 and 4 show the analysis results of the separated model analysis. Fig. 3 represents containment and IRWST pressure, and Fig. 4 depicts the temperature variation of those compartments. The distribution of pressure and temperature has a little difference on containment and IRWST. As steam goes to IRWST, the pressure of IRWST increases at early time of the transient. However, the state becomes thermally stratified and is maintained as equilibrium state.

As a result, the effect of steam condensation was not distinct although steam condensation seems to appear at early period of the transient. The main reason of this result is that heat transfer system of interest herein is stable along with axially stable design characteristics.

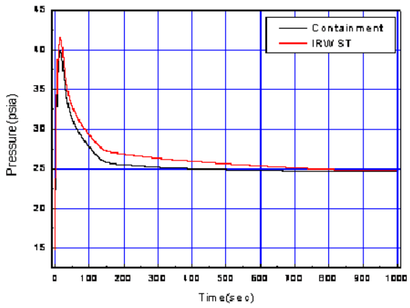

Fig. 3 Containment Pressure by Separated Model

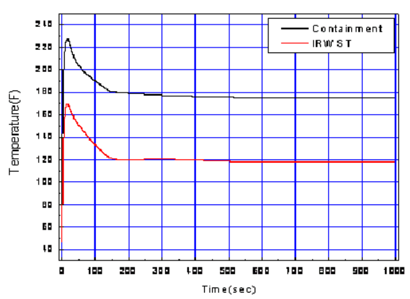

Fig.4 Containment Temperature by Separated Model

Fig. 5 and 6 show the results of 3-D model for IRWST analysis. The results imply that the PRDs give a little impact on pressure distribution between upper compartment and IRWST. Steam condensation on pool surface cannot be distinct in the thermally stable condition. In other word, it is not effective due to low steam and high non-condensable concentrations of IRWST atmosphere.

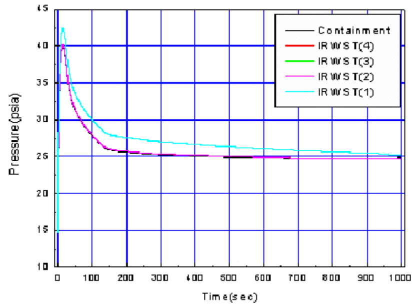

Fig. 5 Containment Pressure by IRWST 3-D Model

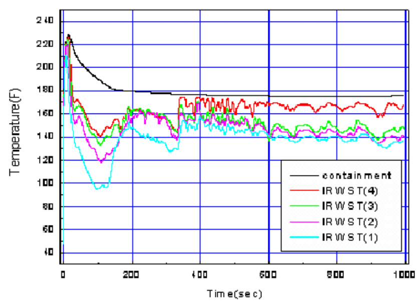

Fig. 6 Containment Temperature by IRWST 3-D Model

4. Conclusions

To investigate the condensation effect at IRWST on containment pressure and temperature in APR1400, analysis model with GOTHIC 6.0 code was developed and fundamental analyses were preformed.

The analysis results show that both IRWST and containment become thermally stratified and is maintained as equilibrium state except for the early period of the transient. This finding means that the condensation between steam and IRWST water surface has minor effect on containment pressure and temperature.

REFERENCES

[1] NAI 8904-02, "GOTHIC Containment Analysis Package User's Manual," Numerical Application Inc., V. 6.0, December, 1997.

[2] APR1400 Standard Safety Analysis Report, Korea Hydro & Nuclear Power Co., Ltd., 2002.

[3] B.C. Lee, et al., “Model Development and Evaluation of Containment Back Pressure by IRWST Damper of APR1400,” A03NJ02, KHNP, 2006. 2. 28.