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Containment Behavior after End Fitting Failure Accident in CANDU-6 Plant

Hoon Choi[a], Yun-ho Kim[a], Kwangho Lee[a], Sung-min Kim[b]
[a] *Korea Electric Power Research Institute, 65 Munjiro, Yuseong, Daejeon, 305-760, Korea*
[b] *Korea Hydro & Nuclear Power Co., LTD, 508 Keumbyeong-ro, Yuseong, Daejeon, 305-343, Korea*
corresponding author : choon@kepri.re.kr

1. Introduction

End fitting failure accident in CANDU-6 plant is one of the design basis accidents. The total amount of mass and energy discharged into containment building from primary heat transport system is similar to that of small loss of coolant accident. But, in case of end fitting failure accident, ejection of fuel bundles into fuelling machine room is unique phenomenon and causes radio nuclides release from the physically broken fuel rod. The final objective of containment behavior analysis is to assess the amount of radio nuclides release to the ambient atmosphere. Current analyses shown in safety analysis report were done with PRESCON2 code developed by Atomic Energy of Canada Limited. In these days, GOTHIC code is adopted as the industrial standard tools for CANDU power plant. Thermal hydraulic behavior after end fitting failure accident is analyzed with GOTHIC and compared with PRESCON2 results.

2. Analysis Method

In containment thermal hydraulic behavior analysis, there are five different set of assumptions according to the objective of analysis. For the end fitting failure accident, the peak pressure, differential pressure, hydrogen concentration and pressure dependent signal analyses are bounded by larger break accident. Only the radio nuclide release amount is a matter of interest [1]. Assumption and analysis model is prepared for this analysis object.

2.1 Assumption

Various pressure and temperature suppression measures are prepared for containment of CANDU-6 Plant. Dousing spray water is reserved in the upper part of containment building and shall be sprayed with pre-determined trip set point. Dousing spray can suppress the pressure and temperature increase at beginning of accident. Spray water can washout some amount of radio nuclides also. Another measure is local air coolers in each compartment. Local air coolers provide long term pressure and temperature suppression. To get conservative results of radio nuclide release analysis, effects of pressure and temperature suppression measures are under-estimated and additional heat sources are considered. Dousing water sprayed into containment through nozzles mounted on 6 headers. But 4 headers are assumed to be available. 35 local air coolers are installed in each compartment, especially 8 local air coolers in steam generator room and 4 local air coolers in each of two fueling machine rooms. Only 8 local air coolers, 4 in steam generator room and 2 in each of two fueling machine rooms, are assumed to be available. And the temperature of 39℃ is assumed for the re-circulated cooling water, the heat sink of local air cooler. It is the highest temperature in the summer. Additional heat sources inside containment come from motors, lights, the reactor face and reactor piping. During normal reactor operation, the total heat load is assumed to equal to the total cooling capacity of operating local air coolers. After an accident and following reactor trip, the heat loads are expected to decrease. But all additional heat sources are determined with the reactor operating at full power, and are assumed constant throughout the accident.

2.2 Containment Model

The compartments of containment building are modeled with 15 nodes and 74 flow paths [2]. Compartments linked with opening are lumped into on node. Fig. 1 shows the nodes and flow paths of model. The free volume of each node is calculated by subtracting the volume of the major equipments installed in the node from the actual total volume of the node. GOTHIC requires node parameters such as elevation, height, hydraulic diameter and liquid-vapor interface area. These parameters are obtained from CANDU-6 plant drawings. The liquid-vapor interface area of each node is set to the node floor area. Doors, openings and opening with blowout panel are modeled as flow paths. Flow path parameters including elevation, height, area, hydraulic diameter, length and resistance coefficient are required.

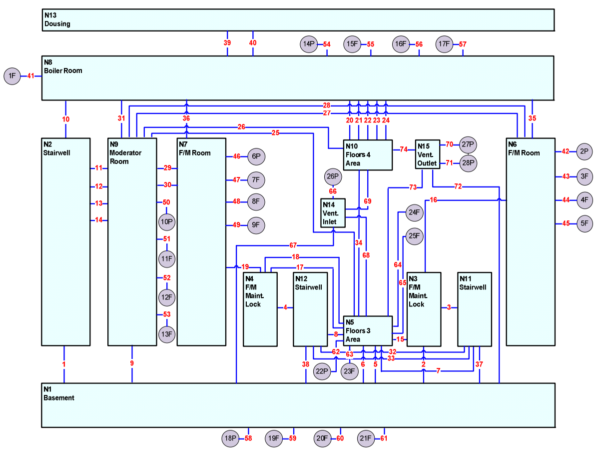

Fig.1. Nodes and flow paths of containment model

Concrete walls and structural steel in a containment building are considered as thermal conductors. Walls and structures can behave as a heat source or sink. Ingression of instrument air used to actuate various devices after an accident is modeled as a mass source increasing pressure. The rate of instrument air ingression changes with time and is modeled with forcing function in GOTHIC.

For this analysis objective, the containment building pressure is assumed to be 0 kPa(a) and the air is dry with 0% relative humidity.

In case of the containment system is intact, the leakage through containment wall is the one and only passage through which vapor with radio nuclides release. Laminar and turbulent leakage allows release of 5% of the containment volume per day at the design pressure of 124 kPa(g) is modeled.

Containment isolation activated by pre-determined containment pressure or radio activity is modeled to close all isolation valves and dampers.

As a long term heat sink, emergency core cooling water recirculation system is modeled with flow boundary condition and cooler in sump node.

2.3 Break discharge

The mass and energy discharged into the containment after an accident are calculated system thermal hydraulic code, CATHENA. Mass flow rate and enthalpy at the break point are fed into GOTHIC with forcing function. System pressure in the upstream of break is also used to activate the drop break-up model. The drop break-up model generates drops from the liquid flow from flashing of superheated water and due to hydrodynamic forces on the water. The advantage of using the drop break-up model is that the drop formation will automatically cease as the water temperature becomes sub-cooled [3].

3. Analysis results

Fig. 2 shows long term pressure transient after end fitting failure with all safety system available.

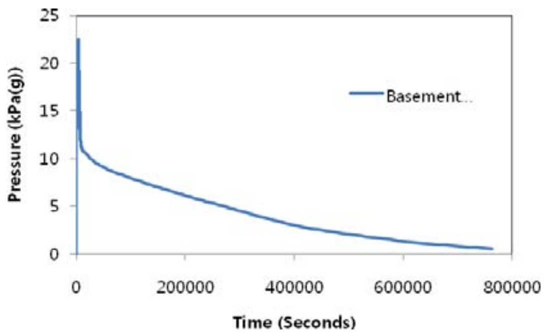

Fig. 2. Long term pressure transient

Fig. 3 shows short term pressure transient. After five dousing cycles, peak pressure reaches to 22.5 kPa(g) at 3913 seconds.

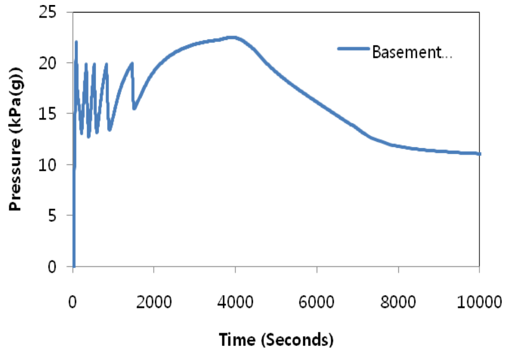

Fig. 3. Short term pressure transient

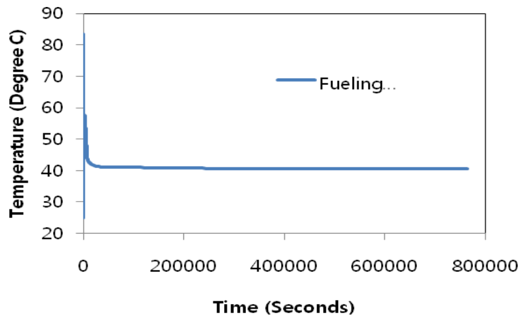

Fig. 4. Long term temperature transient

Fig. 4 shows maximum temperature of 84℃ in the fueling machine room at 96 seconds.

4. Conclusions

Analysis results show almost same peak pressure and a little low peak temperature as those of W-2/3/4. It isf concluded that the change of analysis code from PRESCON2 to GOTHIC has no significant effect on containment thermal hydraulic behavior analysis.

REFERENCES

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[3] T. George, S. Claybrook, L. Wiles, C. Wheeler, GOTHIC Containment Analysis Package User Manual Version 7.2a(QA), 2006