Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Benchmarking Analysis between CONTEMPT and COPATTA Containment Codes

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1. Introduction

The containment is the requirement that the releases of radioactive materials subsequent to an accident do not result in doses in excess of the values specified in 10 CFR 100. The containment must withstand the pressure and temperature of the DBA(Design Basis Accident) including margin without exceeding the design leakage rate. COPATTA as Bechtel's vendor code is used for the containment pressure and temperature prediction in power uprating project for Kori 3,4 and Yonggwang 1,2 nuclear power plants(NPPs). However, CONTEMPT-LT/028 is used for calculating the containment pressure and temperatures in equipment qualification project for the same NPPs. During benchmarking analysis between two codes, it is known two codes have model differences. This paper show the performance evaluation results because of the main model differences.

2. Main Model Differences between COPATTA and CONTEMPT-LT/028

2.1 Tagami condensation heat transfer coefficient

A transient period occurs during blowdown of the primary coolant when condensation on the structures is characterized by forced convection in the containment atmosphere. Tagami developed an empirical correlation, applicable during the forced convection period, which states that the maximum heat transfer coefficient depends on the total energy released from the primary coolant system during the decompression, on the volume of the containment building, and the time required for decompression. This heat transfer correlation can be expressed as

$$h_{\max} = 72.5\left(\frac{Q}{t_p V}\right)^{0.62} \quad \text{;CONTEMPT} \qquad (1)$$

$$h_{\max} = 72.5\left(\frac{Q^*}{t^* V}\right)^{0.62} \quad \text{;COPATTA} \qquad (2)$$

Where, t_p : Time from start of accident to EOB
t^* : Time from start of accident to the first peak pressure

As seen in above equations, Tagami equation is similar each other. However, COPATTA calculates the time(t*) at the first pressure peak internally. However t_p is user input in CONTEMPT.

2.2 Tagami/Uchida transition

The conventional Tagami/Uchida heat transfer option in CONTEMPT-LT is expressed by 'option 53'. It operates inside code as follows;

$$h = h_{max}\left(\frac{t}{t_p}\right) \qquad t \le t_p$$
$$h = h_{Uchida} \qquad t > t_p \qquad (3)$$

As seen in above equation, the condensation heat transfer coefficient abruptly changes from Tagami to Uchida. CONTEMPT has another condensation heat transfer scheme, referred as 'option 55', which can not be found from the code manual but source code has it. This scheme is expressed by exponentially transition from Tagami to Uchida as follows;

$$h = h_{\max}\left(\frac{t}{t_p}\right) + 2 \qquad t \le t_p$$
$$h = h_{Uchida} + (h_{\max} - h_{Uchida})e^{-0.025(t-t^p)} \qquad t > t_p \qquad (4)$$

COPATTA has the condensation heat transfer model which transit exponentially from Tagami to Uchida as follows;

$$h = \max\left[h_{Uchida}, h_{\max}e^{-0.053(t-t_p)}, h_{\max}\left(\frac{R_{wi}}{R_{wi}(t_p)}\right)\right] \qquad (5)$$

where, $h_{\max}$: Tagami peak heat transfer coefficient
R_{wi} : Instantaneous blowdown rate (lb/hr)

From above consideration, the 'option 55' in CONTEMPT is similar to COPATTA's condensation heat transfer model.

2.3 Mass and Energy Model

CONTEMPT has two option for the mass and energy treatment, referred as 'Temperature Flash' and 'Pressure Flash'. Generally, 'Pressure Flash' option results in lower pressure prediction than 'Temperature Flash' option. According to review COPATTA manual, COPATTA has the flash model which is similar to 'Pressure Flash' option in CONTEMPT.

2.4 Containment Spray Heat Transfer

CONTEMPT calculates final specific enthalpy(h_{sf}) of spray droplets after exchanging energy with vapor region with user specified spray efficiency(η_s) as follows;

$$\eta_s = \frac{h_{sf} - h_s}{h_e - h_s} \qquad (6)$$

where, h_s is the specific enthalpy of droplets leaving spray nozzle and h_s is end point specific enthalpy of water in the vapor region prior to spray effects. CONTEMP calculates containment spray heat transfer using the spray specific enthalpy. On the other hand, COPATTA calculates the temperature (T_f) of the spray droplets following heat transfer between the spray and the containment atmosphere with user specified spray efficiency (ε_s) as follows;

$$\varepsilon_s = \frac{T_f - T_{hout}}{T_a - T_{hout}} \qquad (7)$$

where, T_a is the containment atmosphere temperature and T_{hout} is the temperature of water at the spray nozzle. COPATTA calculates spray heat transfer with the temperature difference (T_f - T_{hout})and the specific heat.

3. Evaluation

This section describes the evaluation results for the main model differences between two codes. Figure 1 shows the results for the LBLOCA scenario in the rector coolant pump suction. As seen in this figure, CONTEMPT predictions when 'Pressure Flash' option and exponentially transition option (option 55) from Tagami to Uchida is nearly similar to COPATTA's. In the first peak, Figure 1, 2 shows CONTEMPT 'Pressure Flash' option predicts lower containment pressure than 'Temperature Flash' option. From this comparison, CONTEMPT gives conservative results always when 'Temperature Flash' option and discontinuous transition option (option 53) for Tagami/Uchida transition.

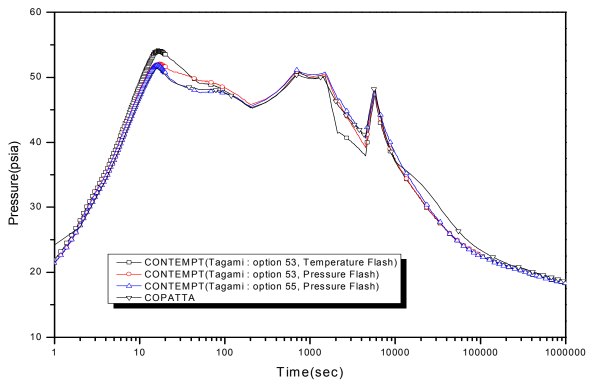

Figure 1 Containment Pressure Prediction (LBLOCA RCP suction break with minimum safety injection)

Figure 2 shows the MSLB results. It is assumed that the core power level is 0% and the breakage is double ended rupture of main steam line. This scenario is selected in this paper because the model difference is apparently represents. For this evaluation, CONTEMPT spray heat transfer model is changed which is similar to COPATTA's heat transfer scheme as described in the previous section. As seen in this figure, CONTEMPT results is nearly similar to COPATTA's when spray heat transfer model like as COPATTA.

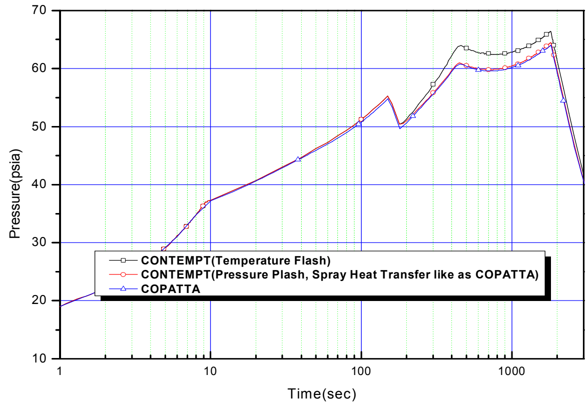

Figure 2 Containment Pressure Prediction (MSLB: 0% power, double ended rupture)

4. Conclusions

In this paper, code performances are evaluated between CONTEMPT-LT and COPATTA because of the main hydrodynamic model differences. The main model differences can be summarized as follows;

- Tagami/Uchida transition
- Mass and Energy Model
- Containment Spray Heat transfer Model

From these model evaluation, it is known that CONTEMPT is always conservative in compared to COPATTA if 'Temperature Flash' option, Tagami/ Uchida transition of option 53 and containment spray heat transfer scheme of CONTEMPT.

REFERENCES

[1] CONTEMPT-LT/028 A computer program for predicting containment pressure-temperature response to a Loss-of-Coolant Accident user's manual, January, 1983.
[2] COPATTA-Containment pressure/temperature transient analysis code, Vol Ⅱ(Theoretical user guide)