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Performance Comparison of Containment PT analysis between CAP and CONTEMPT Code

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1. Introduction

A development project for the domestic design code was launched to be used for the safety and performance analysis of pressurized light water reactors. As a part of this project, CAP (Containment Analysis Package) code has been developing for the containment safety and performance analysis side by side with SPACE code. CAP 2.2 version has been released lately and it is used in the licensing proposal of LOCA analysis methodology with SPACE code. In this proposal, CAP, in the form that is linked with SPACE, computed the containment back-pressure during LOCA accident.

In previous SAR (safety analysis report) report of Shin-Kori Units 3&4, the CONTEMPT series of codes(hereby referred to as just "CONTEMPT") is used to evaluate the containment safety during the postulated loss-of-coolant accident (LOCA). In more detail, CONTEMPT-LT/028 was used to calculate the containment maximum PT, while CONTEMPT4/MOD5 to calculate the minimum PT. Actually, in minimum PT analysis, CONTEMPT4/MOD5, which provide back pressure condition of containment, was linked with RELAP5/MOD3.3 which calculate the amount of blowdown into containment. In this analysis, CONTEMPT4/MOD5 was modified based on KREM.

CONTEMPT code was developed to predict the long-term behavior of water-cooled nuclear reactor containment systems subjected to LOCA conditions. It calculates the time variation of compartment pressures, temperatures, mass and energy inventories, heat structure temperature distributions, and energy exchange with adjacent compartments, leakage on containment response. Models are provided for fan cooler and cooling spray as engineered safety systems. Any compartment may have both a liquid pool region and an air-vapor atmosphere region above the pool. Each region is assumed to have a uniform temperature, but the temperatures of the two regions may be different.

As mentioned above, CONTEMP has the similar code features and it therefore is expected to show the similar analysis performance with CAP. In this study, the differences between CAP and two CONTEMPT code versions (CONTEMPT-LT/028 for maximum PT and CONTEMPT4/MOD5 for minimum PT) are, in detail, identified and the code performances were compared for the same problem.

2. Important Factors in LOCA Analysis

As a part of CAP validation, code by code performance comparison between CAP and CONTEMPT-LT/028 carried out in previous research already. The bottom up comparison strategy, starting from a separate phenomenon to ending up integral problem, was adopted and CAP results in all separate phenomena were comparable to CONTEMPT-LT/028 but in integral problem differed slightly in any cases. In this study, source level comparison was conducted in great detail.

In LOCA analysis, major factors which have an effect on the transient behavior of containment are as follows

- Mass/Energy Blowdown.
- Subcooled steam condensation to liquid
- Wall Condensation model.
- Sensible Heat Transfer model.
- Interfacial Heat and Mass Transfer.
- Spray and Fan cooler Model.

During LOCA, massive coolant is discharged into receiving compartment and the amount of blowdown that flashes depends on its specific enthalpy. In CONTEMPT4/MOD5, user can specify the receiving region (atmosphere or pool), material transferred and multipliers for the mass and energy transfer rates but in CONTEMPT-LT/028, not available. The current version of CAP handles the mass/energy blowdown in the same way with CONTEMPT4/MOD5 and, if same blowdown rate, yields the same data.

When the atmosphere becomes supersaturated, some of the steam will condense to reduce the supersaturation. In this case, CAP allows atmosphere to be metastable condition, that is, atmosphere temperature can be below the saturation temperature at total pressure. This subcooling of the steam is reduced by condensing all steam directly to the pool region since CAP not allows the fog formation. The amount of steam that falls down on pool surface is semi-implicitly decided by simple model proportional to subcooling. For CONTEMPT, an implicit condensing steam calculation, split the water vapor and liquid using quality based on total atmosphere energy, is always performed if the vapor region is not superheated. There was some difference in condensing steam between two codes and this result in slightly different transient behavior of compartment.

Both codes use the Uchida or Tagami correlation for a wall condensation model, which are a favorite model with the containment analysis codes. In most blowdown cases, both codes show the same results because both models have a simple form of correlation. If user selects the Tagami option and the atmosphere becomes superheated during the blowdown period, however, COMTEMPT use the Tagami correlation as heat transfer coefficients and saturation temperature as the bulk temperature. On the other hand, CAP does nothing or calculates the sensible heat transfer by user options.

When the wall temperature is greater than the saturation temperature of phase temperature, sensible wall heat transfer is occurred. Basically, in the situation, both codes use the same heat transfer coefficient (McAdams' turbulent natural convection coefficient). However, there are some differences in the way Grashof number variables are decided. Also, CONTEMPT assign the minimum heat transfer coefficient (0.19 Btu/hr-ft^2-^{o}F) if wall temperature difference is less than 1.0 ^{o}F but CAP has no limit.

Heat and mass transfer at the pool surface between atmosphere and pool is compared. Both codes use the heat and mass transfer analogy to treat interfacial transfer phenomena. Most noticeable difference of interfacial heat transfer model is the interfacial temperature; a saturated temperature at steam partial pressure in CONTEMPT, while any temperature calculated by iterative solution in CAP.

These spray systems were installed to condense steam and reduce the pressure threat to containment or maintain drywell integrity in the event of a design-basis, large break in the reactor coolant system. Fan cooler units circulate the containment atmosphere past cooling coils and thereby remove energy from the atmosphere and condense the steam in the atmosphere. Spray and fan cooler play important roles in LOCA analysis. In this research, therefore, thermodynamic transient behavior by spray and fan cooler is compared in detail between both codes.

3. Calculation Result

The maximum PT analysis for DEDLSB and MSLB (by CONTEMPT-LT/028) and the minimum PT analysis for ECCS performance (by COMTEMPT4/MOD5) are compared with those of CAP. For example, figure 1 and 2 shows the comparison result on maximum PT analysis of DEDLSB accident before and after taking into account the differences that identified between two codes in chapter2. CAP results after modification correspond exactly with those of CONTEMPT-LT/028.

4. Conclusion

Code by code comparison was carried out to identify the difference of LOCA analysis between a series of COMTEMPT and CAP code. With regard to important factors that affect the transient behavior of compartment thermodynamic state in loss of coolant accident, the in-depth comparison analysis is conducted. After identifying the differences in each factor, CAP source code modified to confirm whether or not it shows the same results as those of a series of CONTEMPT code. In most cases, the exactly same results are revealed.

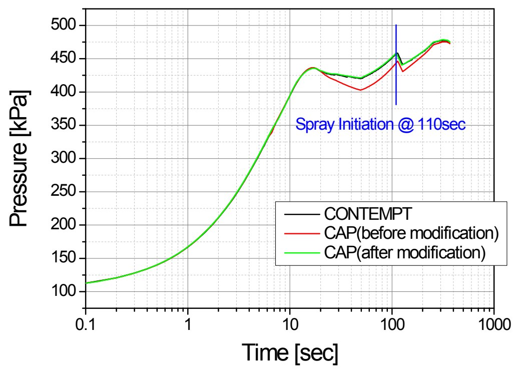

Fig. 1. Pressure Transient of Integral Effect Comparison

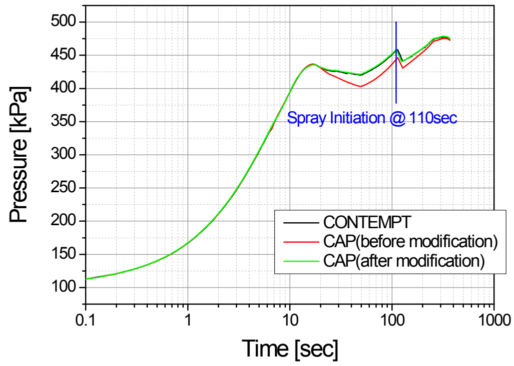

Fig. 2. Temperature Transient of Integral Effect Comparison

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