Comparison COMPARE/MOD1A with GOTHIC 8.0 from the subcompartment pressurization analysis point of view

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1. Introduction

Nuclear power plant subcompartment analyses are required to determine the subcompartment pressure distribution that might result from postulated high energy line breaks. The pressure distribution is used to calculate structural design loads and asymmetric pressure loading.

Subcompartment analysis has been done conveniently by computer codes such as COMPARE, which is used by the US Nuclear Regulatory Commission (US NRC) and analysts in the United States and Europe. However, since the COMPARE code utilizes several simplifying assumptions to facilitate solution of the complex transient, two-phase and multidimensional flow problem, the results from the COMPARE code tends to be too conservative. It is needed that the newly introduced thermal-hydraulic code be applied in the subcompartment pressurization analysis. Recently, the GOTHIC is rapidly becoming an industry-standard computer code in containment thermal-hydraulic analyses and widely used by AP1000, US-EPR and US-APWR for their containment design.

In this paper, subcompartment analyses for the APR1400 Main Steam Valve House (MSVH) due to a Main Steam Line Break (MSLB) by using COMPARE/MOD1A and GOTHIC 8.0 are compared to demonstrate the applicability of the GOTHIC code for the subcompartment pressurization.

2. Description of COMPARE and GOTHIC code

2.1. Description of COMPARE code

The COMPARE code has provision for the transient calculation of conditions in a system of volumes (as many as 100) connected by vents (as many as 200). Each volume is assumed to be a stagnant homogeneous mixture of steam, water, and/or any three perfect gases. Heat conduction structures (as many as 20) may exist in the volumes. Typically, a steam-water-air mixture exists within a subcompartment during the course of a transient. Water mass and/or energy addition into as many as five individual volumes is provided.

A quasisteady-state approximation with a correction for fluid inertia effects is used to represent the transient processes. Mass and energy inflow or outflow accounting, for each volume, is first accomplished for the particular time increment, assuming vent flows are constant. Thermodynamic equilibrium is then assumed and state points determined. The resulting volume thermodynamic conditions are assumed to be constant and used to calculate the new vent flows from or into volumes for the next time interval.

2.2. Description of GOTHIC code

GOTHIC is an integrated, general purpose thermal-hydraulics code for design, licensing, safety and operating analysis of nuclear power plant containments, confinement buildings and system components. GOTHIC has a flexible noding structure that allows both lumped parameter and 3-D modeling capabilities.

GOTHIC solves mass, energy, and momentum conservation equations for the multi-component, multi-phase flow. Conservation equations are solved for three fields: vapor (steam/gases mixture), continuous liquid, and droplets. The vapor field is composed of steam and non-condensing gases. The gases and steam are assumed to be homogeneously mixed and in thermal equilibrium within a computational control volume.

GOTHIC models the heat transfer between solid structures and/or contacting liquid or steam/air mixtures. Thermal conductors are modeled as one-dimensional heat structures. Boundary conditions may be specified for determining the heat transfer from/to the structure.

3. Analysis Results

3.1. Analysis Model

The MSVH is one subcompartment defined as partially enclosed volume within the auxiliary building that houses high energy piping and would limit the break flow to the outside atmosphere in the vent of postulated pipe rupture within the node. The MSVH encloses and supports safety-related equipment such as main steam isolation valves, main feedwater isolation valves, main steam safety valves, and main steam relief valves and pipes.

As per branch technical position (BTP) 3-3 B. 1. a. (1), a 0.09 m^2 (1.0 ft^2) break area in a main steam line is postulated. Considering blowdown mass and energy release rates due to the MSLB with the MSVH volume, vent area and its flow behavior, a transient differential pressure response analysis is performed.

Figure 1 depicts the schematic diagram of MSVH in APR1400. As shown in figure 1, MSVH has two vent paths in both lower and upper parts. Those two vent paths can form flow path to relieve pressurization of the MSVH when the postulated high energy line breaks occur.

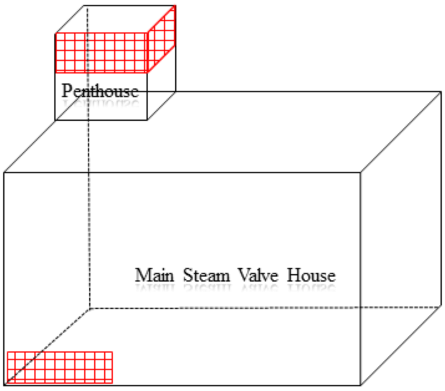

Fig. 1. Schematic diagram of MSVH

3.2. Analysis Results

The comparison between COMPARE/MOD1A and GOTHIC 8.0 is performed to be consistent with common practice.

For the analysis consistency for comparison, each node and junction information where node volumes, heights, hydraulic diameters and loss coefficients are contained as input data remain the same as far as possible between two codes.

Considering the junction connection between two vertical nodes in GOTHIC model, the length corresponding to one (1) percent of the MSVH volume height is assumed for all ceiling and floor junctions.

In addition, the initial conditions for pressure, temperature and relative humidity are set to 1.03 kg/cm^2A (14.7 psia), 40 ℃ (104 ˚F) and 0.0 %, consistent within two codes. With regard to heat transfer options, it is normally neglected for subcompartment pressurization analysis due to early peak pressure in the transient; the peak calculated pressure normally occurs within 1 sec.

As for the GOTHIC Drop Liquid Conversion option, it is set to IGNORE to prevent drop phase entrainment agglomeration, and deposition in accordance with the Standard Review Plan (SRP) 6.2.1.2.II.B.4.

Figure 2 shows the comparison of MSVH pressurization results from COMPARE/MOD1A and GOTHIC 8.0 code. According to Figure 2, the pressure for node 1 and node 2 are only described because the major concern is the highest peak pressure in a volume among all sub-nodes modeled in the subcompartment pressurization analysis.

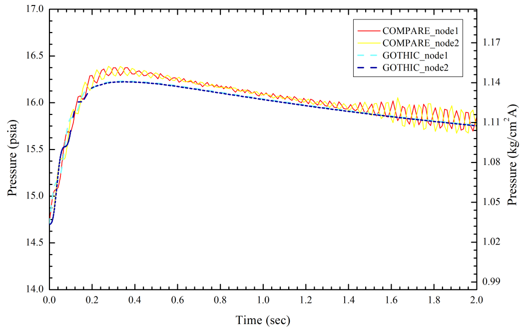

Fig. 2. Comparison of MSVH pressurization results between COMPARE/MOD1A and GOTHIC 8.0

4. Conclusion

From Figure 2, the peak calculated pressure is estimated to 1.15 kg/cm^2 (16.39 psia) from COMPARE/MOD1A and 1.14 kg/cm^2 (16.23 psia) from GOTHIC 8.0, respectively. The node peak calculated pressure difference is within less than 1% of each other and occur at nearly the same time after the start of the transient.

A comparison between COMPARE/MOD1A and GOTHIC 8.0 demonstrates that COMPARE/MOD1A and GOTHIC 8.0 results are very similar.

Based on the above, since COMPARE/MOD1A is an applicable licensing code for the subcompartment analysis of nuclear power plants, it is concluded that GOTHIC 8.0 which shows a similar thermal-hydraulic behavior with COMPARE/MOD1A is an acceptable code for PWR subcompartment pressurization analysis.

REFERENCES

[1] COMPARE-MOD 1: A Code for the Transient Analysis of Volumes with Heat Sinks, Flowing Vents, and Doors, LA-7199-MS, March 1978.

[2] COMPARE-MOD 1 Code Addendum, NUREG/CR-1185 LA-9199-MS, June 1980.

[3] GOTHIC-Thermal Hydraulic Analysis Package-User Manual, Version 8.0(QA), NAI-8907-02 Rev 20, January 2012.