Evaluation of CFVS Performance with SPARC Model and Application

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1. Introduction

Containment Filtered Venting System (CFVS) is one of the important safety features to reduce the amount of released fission product into the environment by depressurizing the containment. KAERI has been conducted the integrated performance verification test of CFVS as a part of a Ministry of Trade, Industry and Energy (MOTIE) project. Generally, some codes are used in the case of wet type filter, such as SPARC, BUSCA, SUPRA, etc. Especially SPARC model is included in the MELCOR to calculate the fission product removal rate through the pool scrubbing [1,2].

In this study, CFVS performance is evaluated using SPARC model in MELCOR according to the steam fraction in the containment. The performance is indicated with decontamination factor (DF). To observe the DF, CFVS individual model input is prepared using MELCOR. In addition, existing study on the severe accident in OPR1000 with CFVS is applied to the results and it is suggested that optimal operation strategy of the CFVS [3].

2. CFVS Model in MELCOR

To understand the CFVS performance in a fixed condition, CFVS individual module is modeled and it is shown in Fig. 1. It consists of three kinds of control volumes; containment, CFVS building, and environment. In the CFVS building, water is filled and the water height is set to 3.0 m. There are two flow paths, one is located between containment and CFVS building and the other one models the flow path from CFVS building to environment. There is a control valve in the path between CFVS building and environment. The valve open fraction is regulated by considering the flow rate

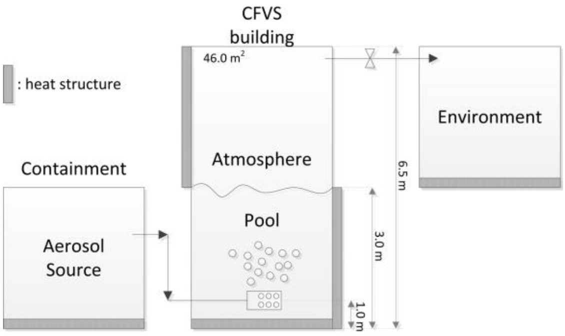

Figure 1 CFVS module model using MELCOR

in the flow path between containment and CFVS building. Aerosol source is installed in the containment and total aerosol mass in the containment is remained the same by adding the same amount of aerosol which enters the CFVS building. Cesiumiodine (CsI) is uses as representative aerosol. The vent type is multi-hole sparger.

2.1 Operating condition

In order to make thermo-hydraulic condition in the containment, steam fraction should be considered. The saturation vapor pressure is indicated in Fig. 2, and the gas condition in containment before entering the CFVS should be located in the region expressed with black spot below the saturation vapor pressure curve. The DF is calculated in the region and five different temperatures of containment are chosen from 384.5 K to 448.5 K. The temperature is the saturation vapor temperature at 1.5, 3.0, 5.0, 7.0, 9.0 bar. Steam fraction in the containment is also changed at the temperature from 0 to 80%. Each spot below the saturation vapor pressure in Fig. 2 represents containment pressure and relative humidity at the temperature. For example, 3 bar, RH80 in Fig. 2 means that the containment pressure is 3 bar and relative humidity is 0.8 at 406.67 K. Above the saturation vapor pressure curve, there are several hollow spot. All hollow spot has relative humidity of 0.8 at the temperature, and the total gas pressure is indicated in vertical line.

2.2 Thermo-hydraulic Condition

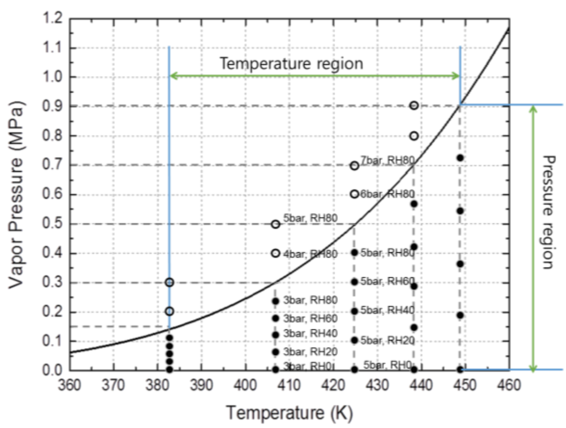

Figure 2 Gas thermo-hydraulic properties in containment

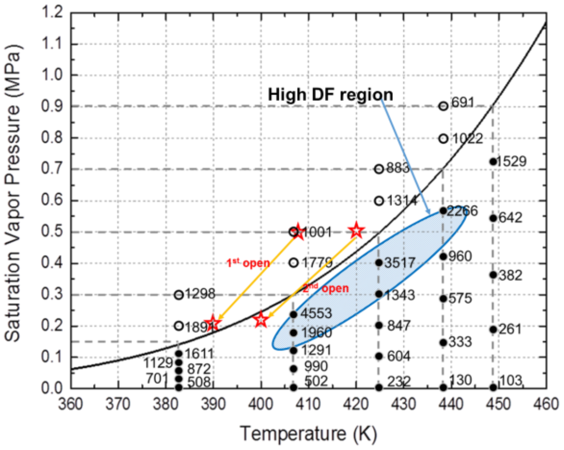

Figure 3 DF results and CFVS operating condition in OPR 1000 SBO accdient

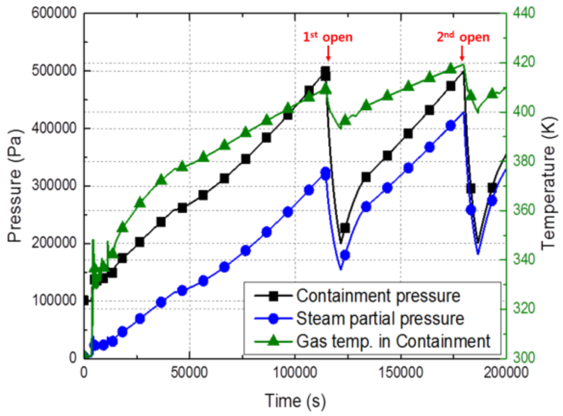

Figure 4 Pressure, steam partial pressure and temperature behavior of containment in OPR 1000 SBO accident

Main purpose of the study is to evaluate the CFVS performance. Thus it is important to fix the thermo-hydraulic conditions in the CFVS building. The conditions, such as water level, water temperature, gas temperature, in the CFVS building can be changed. This is because that the water level is affected by the steam fraction and temperature is also affected by the gas temperature in the containment. In this study, the pool temperature and water level are set to 290 K and 3.0 m, respectively.

3. Results

In this section, CFVS performance evaluation data is indicated, as decontamination factor. The results are explained with SPARC model. With the result, CFVS operating strategy is presented in the case of OPR1000 using previous study result.

3.1 CFVS Performance

Decontamination factors obtained from the MELCOR calculation are indicated in Fig. 3. Generally lower DF is observed as the containment pressure increased except for the case of 1.5 bar. As the steam fraction is increasing, DF is also increased. In SPARC model, the DF is calculated in two regions, globule region and swarm region. In the globule region, inertial impaction and steam condensation are important aerosol removal mechanism. In the case of steam condensation, DF is decided by comparing the mole fraction of non-condensable gas in the containment and CFVS pool. Thus the DF value will be increased when the temperature difference is large if it contains a steam. In the bubble rise period, the aerosol is also removed by centrifugal, diffusional and gravitational deposition in the bubble [2, 4]. In the Fig. 3, the DF value in RH80 case is decreased as the pressure increased. In this model, the containment pressure is different and it affects the CFVS building pressure. The gas velocity in the flow path between containment and CFVS building is decided by the pressure difference, and the high pressure difference is observed in the low containment pressure case. Aerosol removal quantity by the inertial impaction mechanism is affected by the gas injection velocity, thus higher DF is observed in the case of 3 bar because of the gas velocity difference. DF at the hollow spot above the saturation vapor pressure curve is also indicated in the Fig. 3.

3.2 Application to OPR 1000 severe accident

In the previous study, severe accident simulation was conducted in OPR 1000 with CFVS [3]. The thermo-hydraulic conditions in the containment, such as gas pressure, steam partial pressure and gas temperature are indicated in Fig. 4. At time is 0 s, station black out accident occurred. The temperature and pressure in containment was increased as the accident progressed. CFVS valve open occurred twice, and the gas condition in containment before and after opening the valve is indicated in Fig. 3 as stellate symbol. The DF at the valve open time could be estimated using the data indicated in Fig. 3. From the data, it would be known that the CFVS performance in second open case is better than first case considering just temperature and pressure. It is found that high DF region is existed and CFVS performance will be increased if operation is conducted in that region.

Although the data indicated in Fig. 3 is conducted in limited condition, it presents the fundamental idea to decide the CFVS valve open time. More data is necessary to generalize the result.

4. Conclusions

Performance of CFVS is calculated by using SPARC in MELCOR, and the proper CFVS operating condition is presented. The calculation is mainly focused on the effect of steam fraction in the containment, and the calculation result is explained with the aerosol removal model in SPARC. Previous study on the OPR 1000 is applied to the result. There were two CFVS valve opening period and it is found that the CFVS performance is different in each case. The result of the study provides the fundamental data can be used to decide the CFVS operation time, however, more calculation data is necessary to generalize the result.

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