# Evaluation of Source Term Release Characteristics of FCVS operation in 1000MWe PWR with MELCOR code

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*When the FCVS is operated, it can prevent the over-pressurization of containment building and reduce the amount of radionuclides release to the environment using pool scrubbing and filter. The effect of FCVS depends on operation strategies, type of nuclear power plants and accident scenarios, etc. In this paper, the characteristic of source term release under SBO in 1000MW$_e$ PWR was evaluated depending on the inlet valve reclosing or staying open. The cases with/without inlet valve reclosing were compared and it was concluded that the inlet valve reclosing or refilling of FCVS vessel pool is required to reduce the amount of source term release to the environment.*

## I. Introduction

The purpose of Filtered Containment Venting System (FCVS) is to prevent over-pressurization of containment and to reduce the amount of radionuclides release to the environment in case of severe accident in nuclear power plants (NPPs). Its effect depends on the type of NPPs, accident scenarios and operation strategies, etc.[1] Therefore, a lot of researches related with FCVS performance were analyzed.[2,4] In this paper, the source term release characteristic is evaluated depending on FCVS operation strategies (reclosing or staying open of inlet valve) in 1000MW$_e$ Pressurized Water Reactor (PWR) by using MELCOR code.

## II. Method

To evaluate the performance of FCVS, the station blackout (SBO) accident was simulated for 1000MW$_e$ PWR by using MELCOR ver. 1.8.6 code. The MELCOR code is a severe accident code to predict the thermal-hydraulic behavior of NPP and release of fission products under the severe accident.[3] In MELCOR code, the radionuclides are classified as 12 classes according to the chemical properties of elements. (Figure 1-(a))[3] Mainly, the class 1 (noble gases) exists as a gaseous form and class 4 (ex. iodine) exists as a fission product vapor state. The aerosols are generated from core meltdown process and molten corium-concrete interaction (MCCI) in cavity after the reactor vessel failure. The geometry of FCVS was modeled with vessel (3 m diameter and 6.5 m height), venting pipe with inlet valve and exhausting pipe.[4] There are pool (initially 4 m height) and filter in FCVS vessel to represent the pool scrubbing and filtration effect. The sparger is composed of 700 holes with 2.524E-5 m$^2$ area for each hole. The level of sparger is 1 m high from bottom of the FCVS vessel.

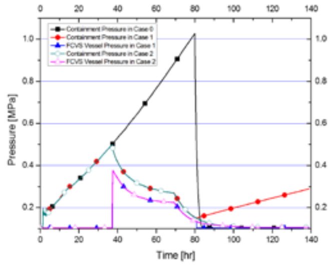
To analyze the source term release characteristics of FCVS operation, three cases were simulated. The case 0 is the base case that there was no FCVS installation and the others included the operation of FCVS. In case 1, the inlet valve was opened if the containment pressure reached at 5 bar and reclosed when it decreased to 1.5 bar. Meanwhile, in case 2, opening pressure is the same but no reclosing at all. Figure 1-(b) shows the pressure behaviors in containment and FCVS for three cases. The containment pressure increased until it reached containment failure pressure or valve opening set point (5 bar) due to steam and non-condensable gases from RCS and MCCI. The containment failed when its pressure reached at containment failure pressure (1.027 MPa assumed) in case 0. In case 1 and 2, once the containment pressure reached at 5 bar, the inlet valve was opened so that the steam, non-condensable gases and aerosols were released to the FCVS. It caused the depressurization of containment until it reached at reclosing set point in case 1 and until it reached the atmosphere pressure in case 2.

## III. Result and Discussion

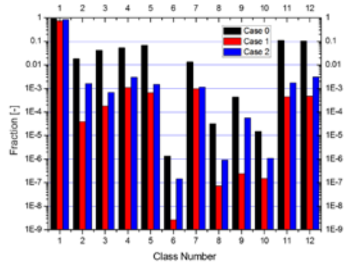
As shown in Figure 1-(d), the containment failed at 80 h in case 0 and the contents in containment released to the environment directly without any decontamination system. The noble gases (class 1) released to the environment about 100 % and the others released about 1.0E-4 % to 10 % of initial inventory. In case 1, the released fraction of radionuclide to the environment was stable because the valve was closed at 80 h (Figure 1-(e)). The amount of radionuclides to the environment in case 1 reduced one or two orders of magnitudes compared with case 0 due to the effect of FCVS. The sparger in FCVS was modeled at the end of the venting pipe submerging into the water pool. In case 2 in absent of reclosing setpoint, the hot steam and fission products gases were released to the FCVS continuously after the inlet valve opening. Due to the heat from steam and fission products, the water level in FCVS vessel decreased to 1 m from the FCVS vessel bottom and the sparger was exposed to the atmosphere of FCVS vessel at 90 h (Figure 1-(f)). After the depletion of pool scrubbing effect, the fission product aerosols in containment were released to the atmosphere of FCVS directly causing increase the amount of radionuclide to the environment (Figure 1-(c) and (f)).

| Class Number and Name | Member Elements |
|---|---|
| 1. Noble gases | Xe, Kr, (Rn), (He), (Ne), (Ar), (H), (N) |
| 2. Alkali Metals | Cs, Rb, (Li), (Na), (K), (Fr), (Cu) |
| 3. Alkaline Earths | Ba, Sr, (Be), (Mg), (Ca), (Ra), (Es), (Fm) |
| 4. Halogens | I, Br, (F), (Cl), (At) |
| 5. Chalcogens | Te, Se, (S), (O), (Po) |
| 6. Platinoids | Ru, Pd, Rh, (Ni), (Re), (Os), (Ir), (Pt), (Au) |
| 7. Transition Metals | Mo, Tc, Nb, (Fe), (Cr), (Mn), (V), (Co), (Ta), (W) |
| 8. Tetravalents | Ce, Zr, (Th), Np, (Ti), (Hf), (Pa), (Pu), (C) |
| 9. Trivalents | La, Pm, (Sm), Y, Pr, Nd, (Al), (Sc), (Ac), (Eu), (Gd), (Tb), (Dy), (Ho), (Er), (Tm), (Yb), (Lu), (Am), (Cm), (Bk), (Cf) |
| 10. Uranium | U |
| 11. More Volatile Main Group Metals | (Cd), (Hg), (Pb), (Zn), As, Sb, (Tl), (Bi) |
| 12. Less Volatile Main Group Metals | Sn, Ag, (In), (Ga), (Ge) |
| 13. Boron | (B), (Si), (P) |
| 14. Water | (Wt) |
| 15. Concrete | (Cc) |
| 16. Cesium Iodide | (classes 2 and 4) |

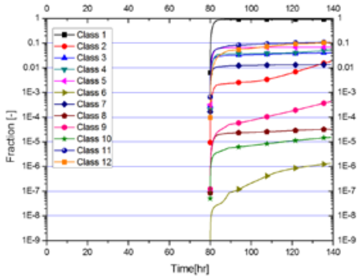
(a) Default Radionuclide Classes and Member Elements in MELCOR code[3]



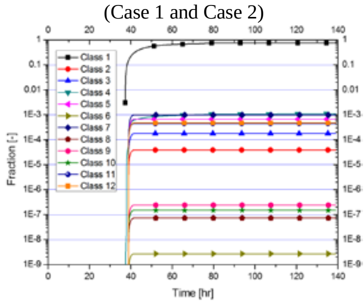

(b) Pressure behaviors in containment and FCVS vessel with/without FCVS installation (Case 1 and Case 2)



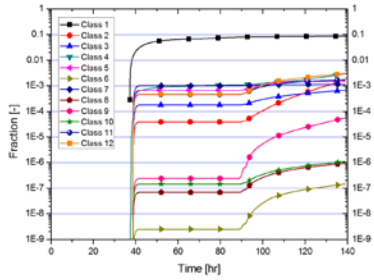

(c) Fraction of radionuclides released to the environment at 140 h




(d) Release fraction to environment without FCVS operation (Case 0)




(e) Release fraction to environment with FCVS operation with reclosing of inlet valve (Case 1)




(f) Release fraction to environment with FCVS operation without reclosing of inlet valve (Case 2)

Fig.1. Pressure and fraction of radionuclides released to the environment.

The characteristics of source term under the SBO accident were evaluated in this paper. When the FCVS inlet valve is not closed, it makes fission product gases and steam release to the FCVS vessel continuously and it induces faster evaporation resulting in the exposure of sparger. If the sparger is exposed to the atmosphere, the incoming gases from containment are released directly to the atmosphere without pool scrubbing effect. Therefore, the release fraction of fission product to the environment increases compared with case of performing reclosing valve. The valve closing is necessary or the refilling the FCVS vessel pool is needed to prevent the large release of radioactive material to the environment.

## ACKNOWLEDGMENTS

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