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Comparison MAAP5.03 with MAAP5.04 from Recombination of CO point of view

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1. Introduction

The severe accidents, which is beyond scope of DBA and cause the onset of core meltdown and lead to releases of combustible gases, such as hydrogen and carbon monoxide. To prevent combustible gases accumulation inside the containment, the installation of Passive Autocatalytic Recombiners (PARs) is employed in generic PWR. For instance as per Post-Fukushima action in Korea, a number of PARs had been installed in all of NPPs in the last few years.

Recently to mitigate Molten Core-Concrete Interaction (MCCI) progress, a limestone-like concrete is used to be selected as the reactor cavity floor material. However because of the fact that they contain higher CO than the siliceous concrete, it leads to a lot of CO generation than siliceous case.

Basically it has been known that PAR can deplete carbon monoxide (CO) as well as hydrogen [1]. But, MAAP5.03 or earlier does not provide the CO recombination model.

To reflect the current issue pertinent to the CO depletion by PARs, the developer of MAAP code, FAI (Fauske &Associate, LLC) implements CO recombination model into MAAP5.04 beta version, very recently.

In this paper, CO concentration for the plant application by using MAAP5.03 and MAAP5.04 beta version are compared to investigate the performance of newly implemented CO recombination model in MAAP5.04 beta version.

2. CO Recombination Model in MAAP5.04 Beta

2.1 Description of PAR

The PAR device presented in Fig. 1 consists of stainless steel enclosure which support for the catalyst material. The enclosure is open at the top and bottom and it extends above the catalyst elevation to cause a chimney effect for additional convective lift to enhance the efficiency of the device. The catalyst material is constrained within cartridges.

2.2 CO generation(chemical reactions)

In reactor building, carbon monoxide is generated on the cavity floor, through chemical reactions between concrete off-gas and core debris. In MAAP5.03 and MAAP 5.04, the chemical equilibrium model is used for CO generation. The Chemical formulas of CO generation are expressed in Eq (1), Eq(2) and Eq(3) [2].

Equation (1) : Free carbon reaction

$$C + H_2O \rightarrow CO + H_2$$

$$C + CO_2 \rightarrow 2CO$$

Equation (2) : Chromium reaction

$$2Cr + 3CO_2 \rightarrow Cr_2O_3 + 3CO$$

Equation (3) : Iron oxidation

$$Fe + CO_2 \rightarrow FeO + CO$$

2.3 CO recombination model

MAAP5.04 beta is modified to extend the current PAR modeling to also recombine CO. Based on experiment result [1], it is concluded that H_2 recombination was not affected by presence of CO [1,3]. This means that the existing H_2 correlations can be used in their current form without any modification in the presence of H_2 and CO. Then, the carbon monoxide recombination rate is estimated from the existing H_2 correlations in Eq (4) by introducing a coefficient as expressed in Eq (5) [2].

Equation (4) : H_2 elimination rate in MAAP 5.03 & 5.04

$$\frac{dm_{H2}}{dt} = -F_s * 29531 * (v_{H2}^{1.307}) * (1 - 0.05 * (P - 1)) * \frac{P}{T} * \frac{1}{3600}$$

Equation (5) : CO elimination rate in MAAP 5.04

$$\frac{dm_{CO}}{dt} = -F_{CO} F_s * 29531 * (v_{CO}^{1.307}) * (1 - 0.05 * (P - 1)) * \frac{P}{T} * \frac{1}{3600} * \frac{M_{CO}}{M_{H2}}$$

Where F_{CO} – CO recombination rate coefficient,
F_s – Coefficient of device type
v – mole fraction of gas,
M_{CO} – molar mass of carbon monoxide,
M_{H2} – molar mass of hydrogen

Fig. 1 Typical design of a PAR [4]

3. Analysis Results

Fig 2 shows the comparison of CO concentration from MAAP5.03 and MAAP5.04 beta. Firstly, since the lower compartment can have a chance of a high concentration of CO due to MCCI, the lower compartment is chosen to be analyzed in the present study. A PAR is assumed to be placed in the lower compartment in the study. At about 80,000 seconds, the reactor pressure vessel is failed and lots of combustible gases and corium are released in the containment building. Until this time, mass of CO is little. But, when corium contacts concrete, CO is generated rapidly. By means of CO recombination provided in MAAP5.04 beta version, apparent CO elimination is confirmed. Secondly the containment dome region, where the hydrogen and CO can accumulated due to light density, with eight PARs installation is analyzed. According to the CO recombination taken into account in MAAP5.04, the most of the CO can be removed by PARs.

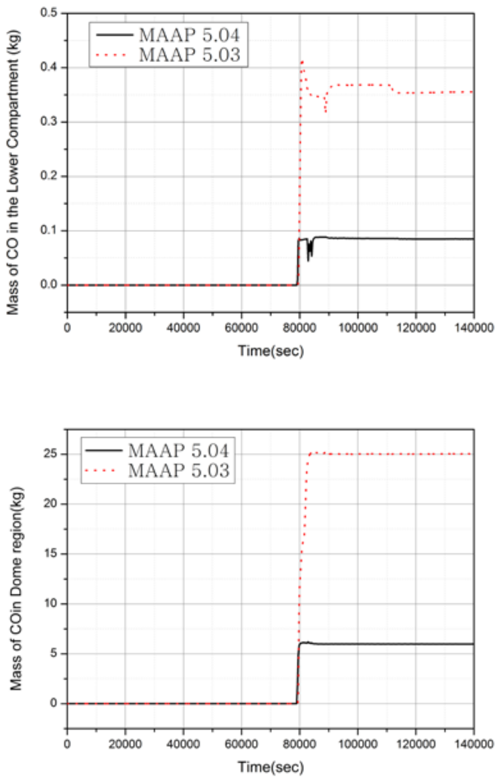

Fig. 2. Comparison of CO mass between results of MAAP 5.03 and MAAP 5.04 beta (top) lower compartment (bottom) dome

4. Conclusion

During severe accident in PWR, carbon monoxide may be released in addition to hydrogen due to MCCI. Because carbon monoxide is combustible gas, mass of CO can have an impact on the containment integrity under the combustible gas combustion.

In the MAAP5.03 or earlier, PAR is modeled such that it can eliminate hydrogen only. Therefore, mass of carbon monoxide is calculated more than reality. To reflect the possible gap of threats from the combustible gas, MAAP5.04 beta version incorporates CO recombination model very recently based on the experiment. According to the CO mass distribution with and without the consideration of CO recombination by PARs, a massive elimination of CO generated by MCCI is predicted in the containment. Consequently, when one employs the CO recombination by PARs as reality, a less threats to the containment can be achieved.

REFERENCES

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