Preliminary Pool Scrubbing Test for Containment Pressure and Radioactivity Suppression System(CPRSS) of SMR

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1. Introduction

The passive containment pressure and radioactivity suppression system(CPRSS) is proposed as a part of the passive containment cooling system to replace the containment spray system,[1] the CPRSS shall have safety functions of 1) suppression of the increase of pressure and temperature (P/T) in the reactor containment area following accidents such as loss of coolant accident (LOCA) and main steam line break (MSLB), and 2) removal of the radioactive fission products from the reactor containment area. The system keeps the reactor containment area P/T from exceeding the design P/T with sufficient margin during 72 hours without AC power sources or operator actions. Figure 1 shows the conceptual view of CPRSS. The reactor containment area in the SMART is divided into a Lower Containment Area (LCA) and an Upper Containment Area (UCA) with the boundary of the CPRSS lid. The CPRSS is comprised of CPRSS lid, pressure relief lines (PRLs) and PRL-spargers, an IRWST, radioactive material transport lines (RTLs) and RTL-spargers, two radioactive material removal tanks (RRTs). The aqueous phase provides optimum conditions for the conversion of non-volatile iodine species to volatile iodine species, where volatile iodine species include molecular iodine (I2) and organic iodides (denoted by RI), and non-volatile iodine species (e.g. I-, HOI, I3−, IO3−) as shown in Figure 2 [2]. The volatile species formed in the aqueous phase could then be transferred to the gas phase at prevailing conditions. Thus, the rates of volatile I2 and RI production/destruction in the aqueous phase are crucial parameters in determining gaseous iodine concentration. In this study, simulation tests were conducted to verify the performance of the radioactive material removal system applied to CPRSS. The RRT and IRWST used in the actual design were simulated in a small cell test.

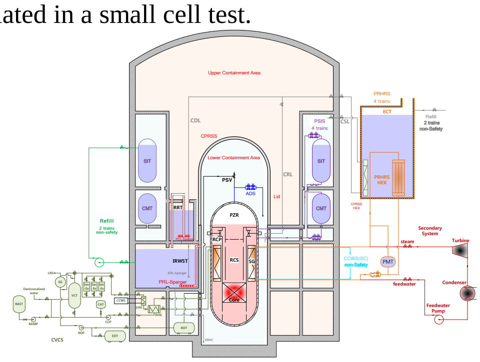


Fig.1 Containment pressure and radioactivity suppression system of SMR

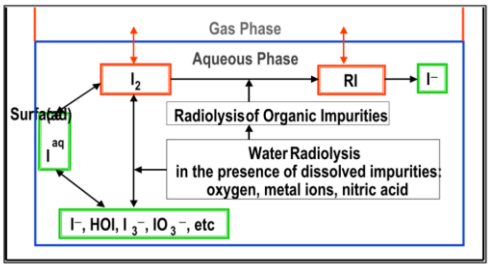


Fig.2 Main aqueous phenomena [2]

2. Test Method and Results

In this experiment, a scrubbing device was constructed for the preliminary confirmation of the radioactive material removal performance of CPRSS. Figure 3 shows an experimental setup that simulates CPRSS. Air flows into A cell and mixes with iodine in A cell and goes to B cell. The amount of air flowing into A cell and the amount of injected iodine are shown in Table 1. Initial pH and temperature conditions of B cell were compared with weak acid and strong alkali.

Table 1 I_2 capture exp. conditions

Air supply and bubble conditions	
Air flow	714 ml/min
I_2 gas injection time	1 hr
B cell nozzle hole No.	4
B cell nozzle hole diameter	1 mm
Bubble diameter	1~2.5 cm
Bubble No.	8~14
Bubble transfer distance	14 cm
Bubble rising velocity	26 cm·s^{-1}
B cell pH and temp.	
pH	4.9 and 10.5
Temperature	25℃ and 80℃

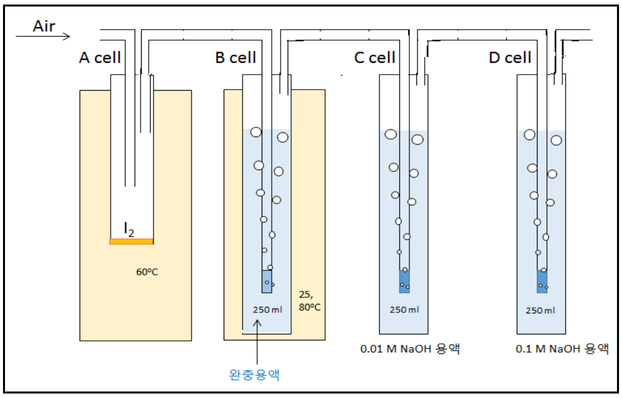
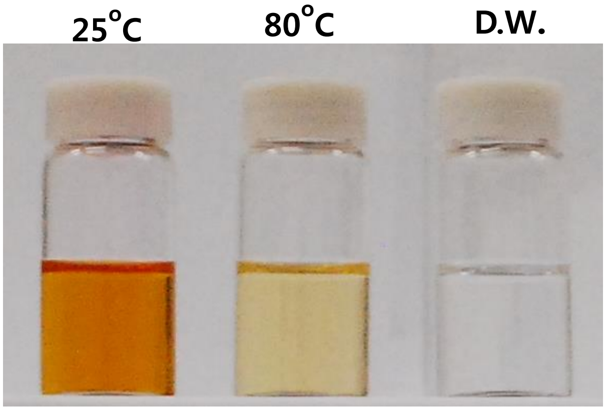


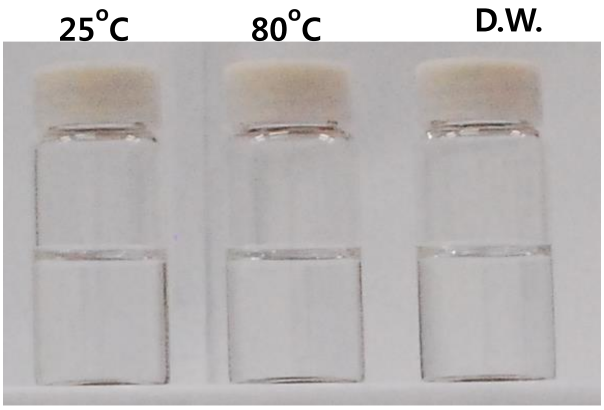
Fig. 3 Scrubbing test facility

Table 2 Decontamination factor

Buffer sol'n pH	**Temp**	**I_2 captured in B cell (gr)**	**I_2 captured in C Cell (gr)**	**DF (=(B+C)/C)**
pH 4.93	**25°C**	**0.072**	**0.076**	**1.94**
	80°C	**0.008**	**0.151**	**1.05**
pH 10.51	**25°C**	**0.129**	**0.00062**	**210.49**
	80°C	**0.131**	**< 0.00032**	**411.31**



(a) pH 4.93 buffer solution(after exp.)



(b) pH 10.51 buffer solution(after exp.)
Figure 4 Solution color and pH variation in the B cell

Table 3 pH after captured exp. in B cell

pH values before exp.	pH values after exp.	
	25℃	80℃
10.51	10.25	10.24
4.93	4.95	4.93

Table 2 shows DF(Decontamination Factor) values according to pH and temperature of the buffer solution. DF values was confirmed as the amount of iodine captured while passing through the B cell and C cell. The air flowing into A cell is finally released to D cell, and iodine is removed by buffer solution and alkaline solution while passing through B cell and C cell. The experimental results show that the DF value at pH 10.51 is much higher than at pH 4.93. It doubles at 80 ℃ than at 25℃. Figure 4 compares the pH and solution color changes in B cell. The iodine molecules in the solution are brown and the ionic form is colorless. I_2 decomposes into ionic form in a pH 10.51 solution, lowering the pH of the solution. On the other hand, I_2 at pH 4.93 is not dissolved and there is no pH change. Table 3 compares the change of pH according to the temperature of the B cell buffer solution after the experiment.

4. Conclusions

In this study, experiments were conducted to confirm the radioactive material removal performance in CPRSS applied to small and medium-sized nuclear power plants. Experimental results showed that iodine was dissolved in the ionic forms that were not re-volatile at pH 10.51, and the DF (Decontamination Factor) value increased at 80 ℃. When solution was acidic, it was also confirmed that the iodine is re-volatile because it exists in the molecular state rather than in the ionic form.

REFERENCES

[1] K.J.Kang, Y.I.Kim et al, Radioactive Material Reduction Facility and Nuclear Power Plant having the same, 10-2014-003632, Korea Patent(2014)

[2] OECD/NEA, State of the Art Report on Iodine Chemistry, Committee on the safety of Nuclear Installation, NEA/CSNI/R(2007)1, 2007