Development of Evaluation System for Iodine Decontamination Factor in Filtered Containment Venting System

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1. Introduction

Modern filtered containment venting system (FCVS) can maintain the containment pressure by releasing the high temperature and pressurized gas from inside the containment to the environment during the severe accidents. During the releasing process, fission products are filtered simultaneously by FCVS to reduce the leakage of radioactive materials to the environment. So, in many countries the implementation of FCVS's is under discussion to mitigate fission product release not only in the short-term but also in the long-term view. Iodine is a major contributor to the potential source term to the environment, therefore, a good understanding of its behavior and validated calculation tools are required to perform meaningful risk analyses and make decisions in the field of accident management, mitigation measures and emergency procedures [1].

The elemental and organic iodides are the main gaseous iodine species in the containment atmosphere. For the iodine retention, experimental programs have confirmed the existence of gaseous organic iodine in some cases in higher concentrations than for gaseous molecular iodine (I_2) [2]. The Reaction of Methyl iodide (CH_3I) with surfaces and the removal by containment filters and scrubbers is less efficient in comparison to molecular iodine. In the recent years, an experimental and analytical work has been conducted at the Paul Scherrer Institute (PSI) to develop a process leading to a fast, comprehensive and reliable retention of volatile iodine species in aqueous solutions [3, 4]. KAERI also conduct the experimental work. This paper introduces the iodine generation and measurement system for the iodine retention test of FCVS. Also, the evaluation methods determining iodine decontamination factor by using ISEs, UV-vise is introduced.

2. Basic Experiment for Iodine Test

2.1 Iodine generation

Due to the experimental environment, the radioactive iodine such as ^{131}I labeled iodine or methyl iodide won't be used in this facility. Gaseous elemental iodine is easily generated by heating solid iodine crystal, because the solid iodine is easily vaporized under 110°C. Fig.1 shows the iodine generation system. The chamber which has the solid iodine crystal up to 500 g is heated by the heated oil to reduce the hot spot. The gaseous elemental iodine is fed by the nitrogen to the main test system. The generation system can be operated at pressures up to 10 bars and temperatures of 150℃.

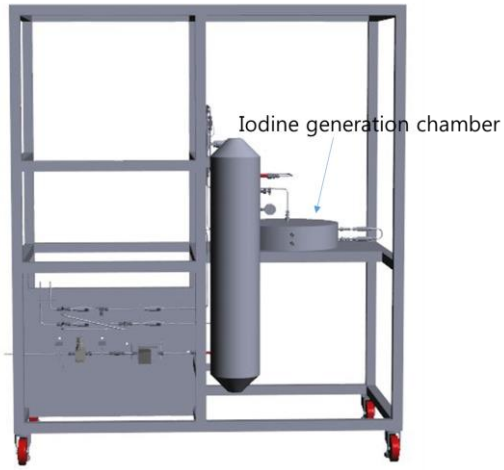
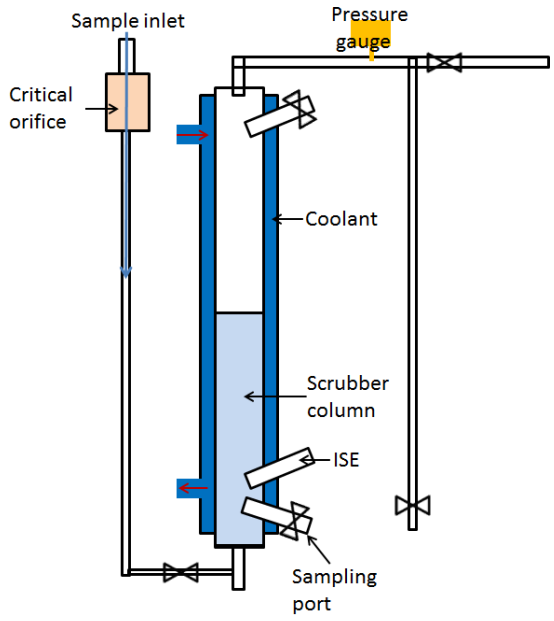


Figure 1 Iodine generation system

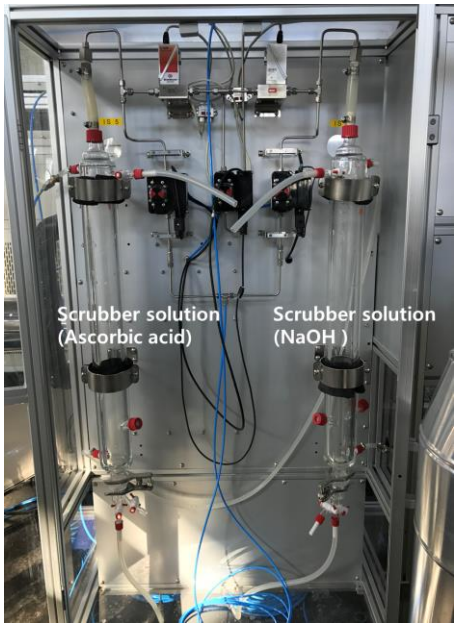
2.2 Iodine measurement

To measure the elemental and organic iodine concentration and to determine DF of the test facility, two different measurement methods based on non-active samples were used. Gas samples were taken simultaneously from the inlet and outlet piping of the test section during the test. The gas sample flow rates can be controlled by calibrated critical orifices which are operated at critical flow conditions by controlling the downstream sampling pressure.

Elemental iodine was sampled to liquid gas scrubber columns with a coolant jacket as shown in Fig. 2. The temperature of the operation gas can reach to near the saturation temperature, the coolant jacket is need to prevent the evaporation of the scrubber solution. It was analyzed by iodide ion selective electrodes (ISE) and Ultraviolet-visible spectroscopy (UV-vis). To use ISE, the scrubber water is doped with ascorbic acid to reduce I2 to I^- ions. Although this system can be used like on-line measurement with ISE, the data indicates the trend of the inlet and outlet concentration, it is not the precise result because ISE is very sensitive to temperature change. To use UV-vis, the NaOH solutions were used for the scrubber water. For the precise result, the calibration work should be performed for the ISEs, UV-vis is after the test under well controlled conditions such as the temperature, and samples are analyzed under same conditions.



(a)



(b)

Figure 2. (a) Schematic diagram of elemental iodine sampling system (b) Experimental set-up

3. Application in FCVS

3.1 1:1 full height FCVS test facility ARIEL

KAERI constructed a large-sized test facility, called Aerosol Removal & Iodine Elimination (ARIEL) test facility, to evaluate the performance of the new Korean FCVS [5]. The key components of the Korean FCVS are the pool venturi scrubber, cyclone droplet/particle separator, metallic fiber filter, and molecular sieve. To verify the performance of FCVS, it is a scaled-down, full height, reduced diameter mock-up of the new Korean FCVS. Two test facilities would be used. One is based on scaling analysis with one venturi nozzle out of total 60 venturi nozzles. Another is based on scaling analysis with three nozzle out of total 60 venturi nozzles to investigate the effect of nozzle arrangement, as shown in Fig.3. Table 1 shows the capacity of the FCVS test facility.

Figure 3. The 1:1 height, reduced diameter scale FCVS facility ARIEL to determine aerosol and iodine retention

Table 1. Capacity of the Test facility

Parameter	Value
Maximum operating pressure	10 bar
Maximum operation temperature	200 ℃
Steam generator capacity	5000 kg/hr
Nitrogen generator capacity	1800 kg/hr
Air supply capacity	1800 kg/hr

3.2 Test in ARIEL

The elemental iodine retention tests have been performed in ARIEL facility. Before the elemental iodine retention test, a series of thermal-hydraulic experiments have been performed to characterize the pressure and temperature behavior and the scrubber water behavior due to heat-up, steam condensation and evaporation as a function of the gas composition of main carrier gas [5].

Table 2. Test condition

Parameter	Value	Value	Unit
Steam mass flow rate	0.079	0.10	kg/s
Nitrogen mass flow rate	0.074	0.10	kg/s
Gas mixture temperature	137~145	145~155	℃
Wall temperature inlet	150	170	℃
Wall temperature test vessel	150	170	℃
Wall temperature outlet	150	170	℃
Inlet pressure	5.06	7.0	bar(a)
Water level	1.45	1.42	m
City water + chemicals pH	13.1	13.1	
NaOH concentration	0.5	0.5	wt%
Sodiumthiosulfate concentration	0.2	0.2	wt%
Experimental time with I2-feed	4	3.5	h

Table 3. Iodine measurement system and analysis method

Location	Measurement system ID	Description	Analysis method
Test Vessel Inlet	IS1	50mM ascorbic acid in de-ionized water	On/Off line ISE
	IS2	0.1M NaOH in de-ionized ater	UV-Vis, ICP-MS
Test Vessel Outlet	IS3	1mM ascorbic acid in de-ionized water	On/Off line ISE
	IS4	0.001M NaOH in de-ionized water	UV-Vis, ICP-MS
Molecular sieve Outlet	IS5	1mM ascorbic acid in de-ionized water	On/Off line ISE
	IS6	0.001M NaOH in de-ionized water	UV-Vis, ICP-MS

The experimental test conditions are given in Table 2. During the test, elemental iodine was sampled to liquid gas scrubber columns as shown in Fig. 2(b). The test facility was configured to perform measurements of the molecular iodine concentrations at the inlet, the outlet of test mockup and the outlet of the molecular sieve. At each location a set of two molecular iodine scrubber columns was installed according to table 3. Samples were collected for off-line measurement with the ISEs, UV-Vis, and ICP-MS. Due to the above mentioned uncertainties caused by bubbling and temperature during the sampling with the on-line electrodes, the off-line sample data are considered more accurate than the on-line ISE data.

In these tests, the concentration of iodine in the gas at the inlet can be easily obtained, it is near 100 ppm. However, it is very hard to measure the concentration of iodine in the gas at the outlet, because the lower limit of the ISE and UV-vis measurement is 0.5×10^{-6} mol/L.

To get more precise DF, samples were analyzed by ICP-MS, ICP-AES. Furthermore, we will try to find new methods.

3.3 Future work

The organic iodine removal test will be performed. The organic iodine will be generated by the two-fluid spraying system, and the target concentration of iodine is in the range of about 5 to 30 ppm. Both the VOC and GC/MS will be used to measure the organic iodine. As the change of the vessel temperature and the pressure, the iodine is re-volatilized from the scrubber pool and a surface of each component. Re-volatilization of iodine test will be performed after elemental/organic iodine removal test.

4. Conclusions

In this paper, the iodine measurement methods to evaluate the performance of FCVS at ARIEL is introduced. Experimental investigation for iodine retention performance were conducted. Decontamination factor for the FCVS is determined by two measurement methods which are ISEs and UV-vis.

ACKNOWLEDGMENTS

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