Current state of gas analysis system of SPARC test facility

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1. Introduction

Hydrogen can be generated in the event of a severe accident. By oxidation reactions occurring between fuel cladding materials and high-temperature steam, hydrogen gas is formed. The hydrogen created in the reactor building can be released into the containment building. Investigations have been performed so as to make strategies and means to control hydrogen concentrations inside the containment building during a severe accident. The investigations concerning the hydrogen behavior inside the containment, distribution, combustion, mitigation and interaction with mitigation measures and safety system have been performed. [1]

SPARC (Spray-Aerosol-Recombiner-Combustion) test facility constructed in the Korea Atomic Energy Research Institute (KAERI) has been utilized for observation of the hydrogen's behavior inside the containment building. Experiments about hydrogen behavior interaction with passive auto-catalytic recombiners (PAR) or spray system have been conducted in SPARC test facility. [2] In these experiments, gas analysis system plays an important role in understanding of a hydrogen gas concentration distribution inside the SPARC pressure vessel. This paper described the improvements of gas analysis system and the calibration of gas analyzers.

2. Methods and Results

Gas analysis system is composed of gas supply system, pre-processing system, gas analyzer and gas venting system.

Fig. 1. The process of gas analysis system of SPARC test facility.

2.1 Pre-processing system

In order to measure gas concentration with gas analyzer, mixture gas must satisfy requirements of gas analyzer. To meet the requirements, mixture gas will start in SPARC test facility, pass through pig tail(cooling coil), condensation trap, dust filter, regulator and dry filter and enter gas analyzer. Pig tail(cooling coil) and condensation trap is the first step in pre-processing system. The role of the pig tail is to reduce the heat of mixture gas. Immediately following, condensation trap including water removes solid or liquid particles of mixture gas. The condensation trap functions as a scrubber. Subsequently, dust of mixture gas is removed by air filter and the pressure is lowered by going through the regulator. For the final stages, dry filter containing silica gel drives the moisture out of mixture gas.

At the SPARC test facility, as shown in Fig. 2. 14 pre-processing systems are already in place. According to the number of pre-processing systems, simultaneous measurement at the fourteen sampling points in SPARC test facility is possible.

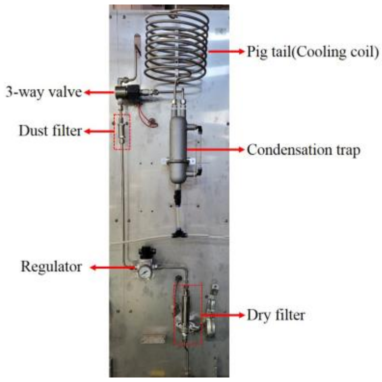

Fig. 2. Current state of Pre-processing system of SPARC test facility.

2.2 Improvement of pre-processing system

For enhancing the response speed of gas analysis system, pre-processing system has been improved. The difference from the past system was volumetric capacity. In other words, the volume of mixture gas passing through has been decreased. As shown in Fig.3, the size of air filter, condensation trap and dry filter has been reduced. Firstly, two dust filters was changed into a dust filter (VFI2U, UNILOK, KOREA). Not only the volume of condensation trap has decreased by about 13 times but also the dry filter has been reduced in size.

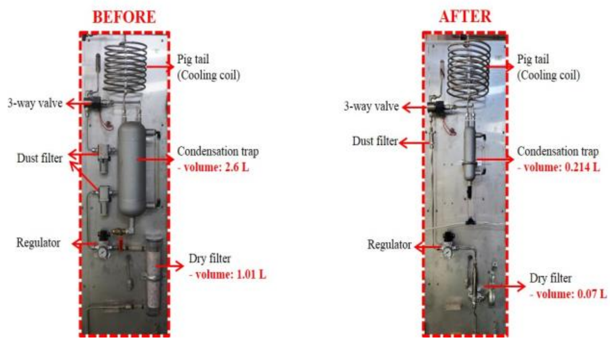

Fig. 3. The pre-processing pictures of before-and-after.

2.3 Pre-processing system test method and results

After upgrading the pre-processing system, tests have been performed to compare the performance of before- and after of pre-processing system. Standard Gas had been supplied to each pre-processing system. The response speed of gas analyzers was evaluated depending on the pre-processing systems.

The test confirms that the response speed of gas analyzers with improved pre-processing system is about 300 sec faster than the response speed of gas analyzers with previous version of pre-processing system.

2.4 Gas analyzer

SPARC test facility is equipped with fourteen hydrogen analyzer for measuring hydrogen or helium concentration and fourteen oxygen analyzers. The hydrogen analyzer (FTC300, Messkonzept GmbH, Germany) is a thermal conductivity analyzer. [3] In the case of oxygen analyzers, four oxygen analyzers (PMA 1000, M&C, Germany) which utilize the paramagnetic measuring principle and eight oxygen analyzers which use electrochemical oxygen sensor were constructed with hydrogen analyzers.

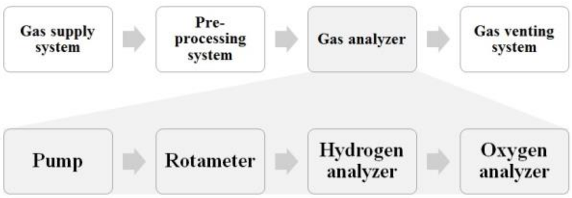

Fig. 4. The process of gas analyzer of gas analysis system.

Table I: Hydrogen analyzer

Manufacturer	Messkonzept GmbH
Model	FTC300
Range	0 ~ 100 %
Accuracy	< 1% of range
Flow rate of sample gas	60 l/h ~ 80 l/h
Gas pressure	Max. 20 bar(abs)
Response time(T90)	< 1 sec at 60 l/h
Measurement principle	Thermal conductivity

2.5 Gas analyzer calibration test method

The objective of calibration test is to adjust the measured concentration to the Standard Gas concentration. Standard Gas is the mixture gas which known the ingredients and the concentration of gas. Calibration Method of gas analyzer is a two-point calibration which requires two kinds of gases, offset/zero gas and gain/span gas. The first step in calibration is zero point calibration by supply offset/zero gas. After zero point calibration, second point calibration has been performed using gain/span gas. After achieving calibration, confirmation process is needed through other Standard Gas. Fig.5 shows the two point calibration of hydrogen analyzers and oxygen analyzers.

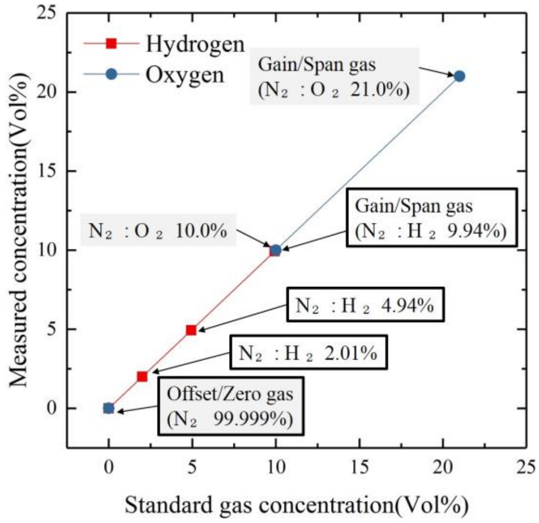

Fig. 5. The method of two point calibration for hydrogen analyzer and oxygen analyzer. [3]

2.6 Gas analyzer calibration test results

For two point calibration of hydrogen analyzers, Standard Gas containing hydrogen and nitrogen have been utilized. High purity nitrogen(99.999% N_2) gas and 9.94% hydrogen and nitrogen mixture gas have been used as offset/zero gas and gain/span gas, respectively. Two kinds of hydrogen Standard Gas were supplied to hydrogen analyzers to check if the two point calibration was performed correctly. As shown in Fig. 6 and Fig. 7, measured concentration is within the margin of error which is 1 % of range.

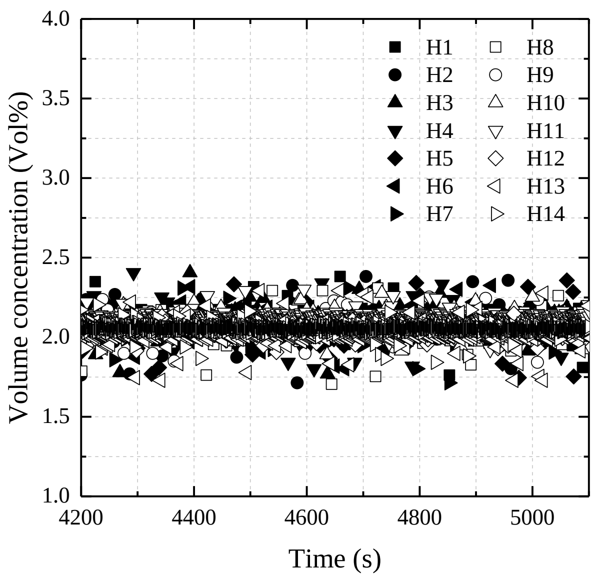

Fig. 6. The measured concentration of hydrogen analyzer when 2.01% hydrogen mixture gas was supplied after performing two point calibration.

Oxygen analyzers have made use of 99.999% N_2 gas and 21.0% oxygen and nitrogen mixture gas as offset gas and gain gas, respectively. The calibration result of oxygen analyzer was examined by 10.0% oxygen mixture gas.

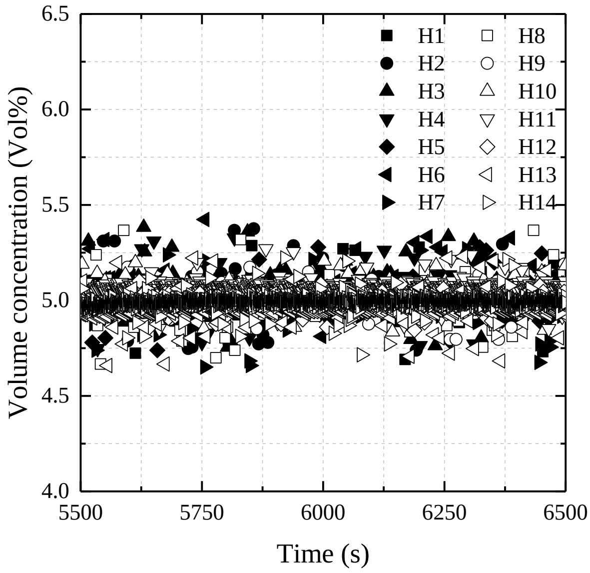

Fig. 7. The measured concentration of hydrogen analyzer when 4.94% hydrogen mixture gas was supplied after performing two point calibration.

3. Conclusions

The pre-processing of gas analysis system has been upgraded to develop the speed of gas analysis system. The internal volume of pre-processing system which the sampling gas pass through has been decreased. The consequence was that the response speed of gas analyzers has increased. Although the dry filter which used in the test is equivalent in volume to 0.08 L, the test results showed that the response speed of gas analyzers was affected by a volumetric capacity of pre-processing system. It was also found from the pre-processing system test that the difference in response speed of gas analyzers was clear depending on the length of sampling tube.

The calibration tests have been conducted for hydrogen gas analyzers and oxygen gas analyzers. The measured concentrations of hydrogen and oxygen analyzers are within the margin of error.

ACKNOWLEDGMENTS

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REFERENCES

[1] OECD/NEA. Status Report on Hydrogen Management and Related Computer Codes; Nuclear Safety NEA/CSNI/R(2014) 8 June 2014; OECD/NEA: Issy-les-Moulineaux, France, 2014.
[2] J. Kim, S-H Hong, J-H Kim and H. T. Kim, SPARC-PAR Experimental Simulation of PAR-induced Hydrogen Stratification, International Workshop on Post-Fukushima Challenges on Severe Accident Mitigation and Research Collaboration, Korea, 2019.
[3] Y. S. Na, S-H Hong and S-W Hong, Calibration test of gas analysis system of SPARC test facility, KAERI/TR-6393/2016.