Current Status of Aerosol Generation and Measurement Facilities for the Verification Test of Containment Filtered Venting System in KAERI

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1. Introduction

At March 11th, 2011, there was a severe accident in Fukushima and a lot of people have been suffered from the damage. In order to prevent the severe accident and reduce the human damage around the nuclear power plant, there are many efforts to develop safety features and establish management rules in the world. Containment Filtered Venting System (FCVS) is one of the safety features to reduce the amount of released fission product into the environment by depressurizing the containment. Since Chernobyl accident, the regulatory agency in several countries in Europe such as France, Germany, Sweden, etc. have been demanded the installation of the CFVS. Moreover, the feasibility study on the CFVS was also performed in U.S [1]. After the Fukushima accident, there is a need to improve a containment venting or installation of depressurizing facility in Korea. As a part of a Ministry of Trade, Industry and Energy (MOTIE) project, KAERI has been conducted the integrated performance verification test of CFVS. As a part of the test, aerosol generation system and measurement systems were designed to simulate the fission products behavior. In this study, the design of aerosol generation and measurement systems are explained and present circumstances are also described. In addition, the aerosol test plan is shown, briefly.

2. Experimental Conditions

The experimental conditions have to reflect the severe accident conditions. The thermo-hydraulic conditions in the containment can greatly affect the performance of the CFVS. Furthermore, the fission product in the containment usually existed in the form of aerosol, and the properties of the aerosol are also important to evaluate the decontamination factor (DF). In order to understand the severe accident conditions, accident analysis was conducted using severe accident integrated code [2]. The experimental conditions are summarized in Table 1 by considering the results. The containment pressure and temperature at the valve open time is assumed to 10 bar(a) and 180^{o}C, respectively. The aerosol concentration in the containment is assumed to 10 g/m^3 at the condition. The various range of steam fraction in the containment is considered from 0 to 100%. Two different sizes of aerosol particle will be used in the experiment, 0.7μ m and 3.0μ m. Silica power (SiO_2) is used to simulate the aerosol particle. It is easy to analyze the result because it is perfect sphere.

Table I: Properties of containment in Severe accident

Property in Containment	Value
Pressure	10 bar
Temperature	180^{o}C
Steam fraction	0~100%
Aerosol size	0.7~3 μ m
Aerosol concentration	10 g/m^3

3. Experimental Setup

In this section, general operation principles of the aerosol generation and measurement system are described and explanations on the component parts are followed.

3.1 Aerosol Generation Equipment

The schematic diagram of the aerosol generation equipment is shown in Fig. 1. In the tank, the aerosol power is mixed with ethanol and the stirrer is operated in the tank. The ethanol is used as the transmitting substance due to the low evaporating temperature. The mixing ratio of aerosol powder in ethanol is set 25~75% by weight. Before injecting the ethanol and aerosol mixture, it is necessary to increase the temperature of the mixture. It helps the evaporation of the ethanol after

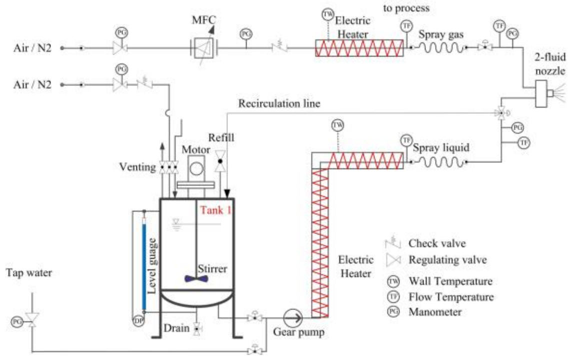

Fig. 1. Aerosol generation system

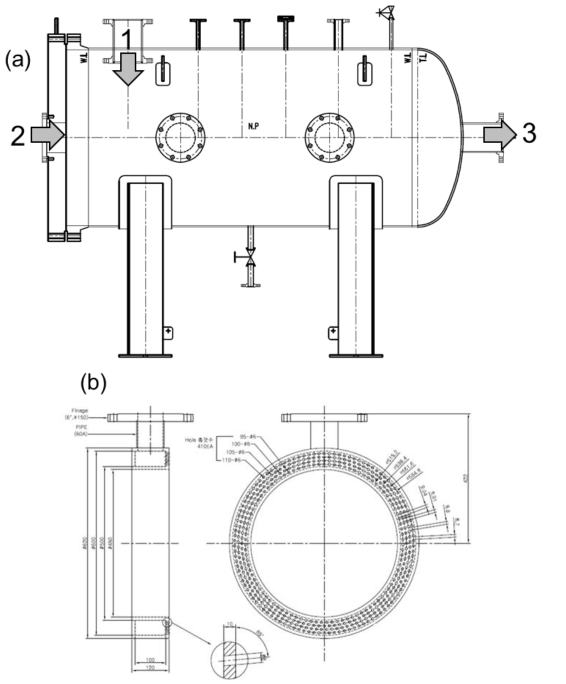

Fig. 2. Mixing chamber structure and distributor. (a) mixing chamber (b) distributor

injection and it prevents the thermophoresis through the pipe [3]. Thus the heating jacket is enclosed around the tank and the line heater is installed in the line between the tank and nozzle. Before reaching the setting temperature of the mixture, recirculation of the mixture will be conducted continuously. The transfer of mixture is performed by using gear pump, which has ability to resist the clogging of aerosol inside the pump. Two-fluid nozzle is employed to spray the mixture and nitrogen (or air) supply line is also installed with line heater.

In order to decide the mixture flow rate, it is necessary to consider the mixing ratio in the tank and aerosol concentration in the containment. For example, the mixture flow rate can be varied from 0.017 to 0.15 Lpm with changing mixing ration in mixing tank to make aerosol concentration of 10 g/m^3. The pressure in the region which contains the two-fluid nozzle is 10 bar(a). To reduce the load on the gear pump, the tank is pressurized to 5~7 bar(a). The gear pump used in this experiment can endure the differential pressure of 8.7 bar. The tank capacity is fixed to 50 Liter considering the mixture flow rate and experiment time. Line heater design is also conducted by considering the fluid flow rate in the pipe and mixture mass in the tank.

The mixture is injected into the mixing chamber to mix the aerosol with main stream gas. In order to distribute the main stream gas well, distributer is installed inside the mixing chamber, as shown in Figs. 2. In Fig. 2(a), mixing chamber is indicated. Main stream gas is supplied at the number 1 and aerosol spray occurred at the number 2. Spray nozzle will be located in the center of the distributer. The distributer consists of the number of 400 small holes, and the front is slightly inclined to help the mixing with aerosol, as indicated in Fig. 2(b). The main stream gas which contains aerosol goes into the number 3, and aerosol concentration and size distribution are measured before entering the CFVS.

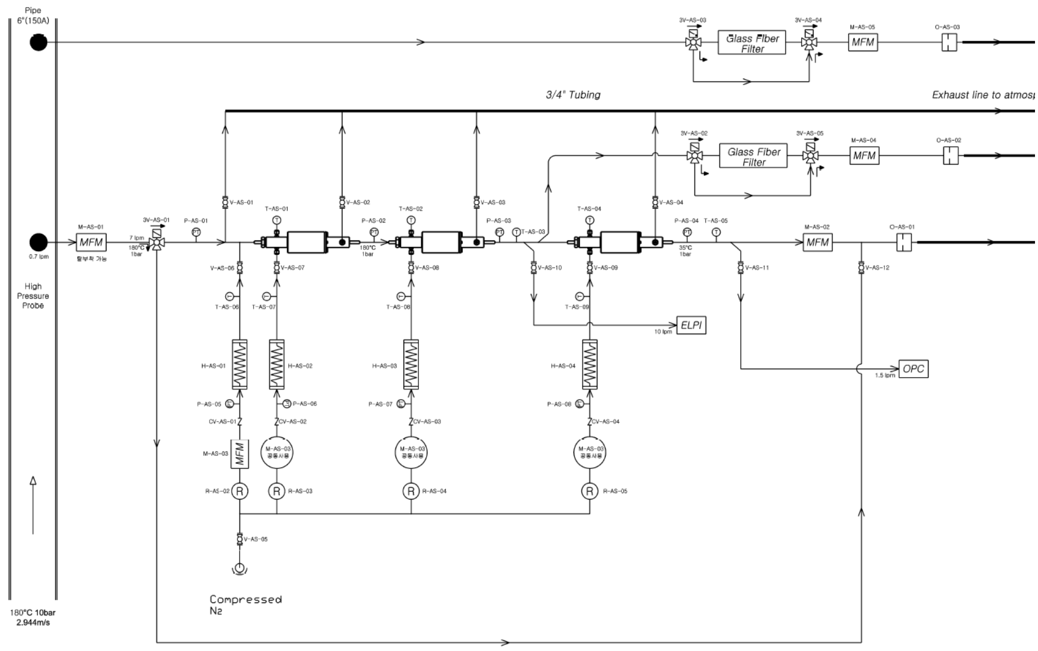

Fig. 3. Aerosol measurement system (inlet)

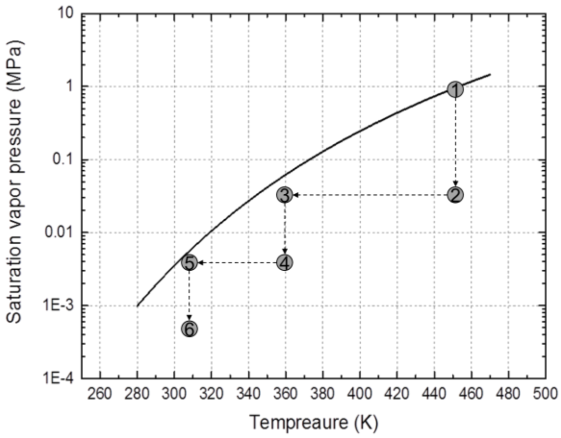

Fig. 4. Temperature and concentration variation of sample gas through diluters

3.2 Aerosol Measurement Equipment

It is very important to measure the aerosol concentration before entering and after passing the CFVS to evaluate the performance of the system with DF. In addition, it is also helpful to understand the aerosol size distribution to know the aerosol removal properties of the CFVS. To measure the aerosol concentration and size distribution, aerosol measurement system is located in inlet and outlet of CFVS, and the system in the inlet is shown in Fig. 3. The basic principle of the outlet system is the same to the inlet system.

As shown in Fig. 3, two sampling nozzles are located in the main stream. One nozzle is employed to measure the aerosol size distribution and the other is used to measure the aerosol concentration. To measure the aerosol concentration accurately, iso-kinetic sampling is necessary to ensure a representative sample [4]. The iso-kinetic sampling will be designed by changing the orifice and sampling nozzle diameter. The aerosol sample enters the sampling nozzle will be accumulated on the filter during the experiment period, and the concentration can be obtained by dividing the accumulated mass with experiment time.

To know the aerosol size distribution, electrical low pressure impactor (ELPI) and optical particle counter (OPC) are employed with diluters. The temperature and aerosol concentration in the main stream is too high to use the equipment. Thus the temperature and concentration is reduced by using one axial diluter and three ejector type diluters. After passing the several diluters, the concentration and temperature are decreased without vapor condensation, as indicated in Fig. 4. Initially, the sampling gas condition is at circle 1, and the position is changed to circle 2 after passing one axial diluter and one ejector type diluter. The gas condition is also changed to circle 4 with one ejector type diluter. Final position is circle 6 with remained ejector type diluter. In this process, the aerosol size distribution can be obtained by using measurement equipment. To prevent the vapor condensation, clean gas temperature supplied to the diluter can be regulated with line heater.

4. Conclusions

To perform the integrated verification test of CFVS, aerosol generation and measurement system was designed and manufactured. The component operating condition is determined to consider the severe accident condition. The test will be performed in normal conditions at first, and will be conducted under severe condition, high pressure and high temperature. Undesirable difficulties which disturb the elaborate test are expected, such as thermophoresis on the pipe, vapor condensation on aerosol, etc. Therefore, it is necessary to estimate the aerosol loss through the system.

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